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Arabic Astronomical Tables in China: Tabular Layout and its Implications for the Transmission and Use of the *Huihui lifa*

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Abstract: This paper examines the early transmission and translation of Arabic astronomical tables in China by comparing the layouts of parallax correction tables. After comparing the layouts of equation tables in various *Huihui lifa* works, this paper concludes that the characteristics of tabular layout are related to the specific nature of each work, and these adjustments thereto may reflect changes in their intended audience and purpose. Comparison of a single type of table that appears in *Huihui lifa* works of different eras in one-dimensional array, two-dimensional array, and rotational symmetry layouts illustrates that Chinese astronomical tables continually absorbed and adapted the advantages offered by Arabic and European counterparts, flexibly adapting them to their own purposes on the basis of their own tradition and habits.

Introduction

When the transmission of Arabic astronomy[1] into China began has yet to be settled. Some scholars believe that it can be traced back to Ma Yize 馬依澤 (921-1005), who in the early Song dynasty (960-1279) came to China from the Near East to participate in the compilation of the *Yingtian li* 應天曆 (implemented c. 964-982) and serve as an official in the Astronomical Bureau.[2]

[1] In this paper we can use the term "Arabic astronomy" or "Islamic astronomy" to describe the *Huihui lifa* tradition in China.

[2] Chen Jiujin 陳久金 (1996), p. 52.

However, the majority of scholars believe that it began only in the Yuan dynasty (1271-1368), when we begin to have clear records of an 'Islamic Observatory/Astronomical Bureau' (*Huihui sitiantai* 回回司天臺) and the activities of Huihui 回回 'Islamic' astronomers in China. For example, we know that the Yuan court established astronomical agencies administered by Huihui astronomers in Shangdu 上都 and Dadu 大都, which enjoyed a number of Near Eastern astronomical instruments and a large collection of Arabic-language works on astronomy/astrology.

The earliest record of Arabic astronomical tables in China is found in the Yuan dynasty book *Mishujian zhi* 秘書監志 (Records of the Bureau of the Imperial Secretariat). Originally, the Imperial Secretariat was the organ of the Yuan government charged with the collection of books.[3] In 1263, the Mongol rulers established an office for Islamic astronomy/astrology, the Directorate of Western-region Astrology (*Xiyu xinglisi* 西域星曆司), and in 1271 they further established the Islamic Observatory, which they placed under the supervision of the Arab astronomer Zhamaluding 紮馬魯丁 (Jamāl al-Dīn).[4] Then in 1273, the Islamic and Chinese observatories were consolidated under the management of the Bureau of Imperial Secretariat. At the time, the Northern (Islamic) Observatory reported an itemized list of the Arabic and Persian books and astronomical instruments in its care. That list, as it is preserved in the *Mishujian zhi*, records the names of 13 books and instruments as transliterated from the Arabic.[5]

It is important to note that this list records a *Jichi zhujia li* 集尺諸家曆 (Mathematical Astronomy of the Various Schools of *Jichi*) in 48 volumes—*jichi* being a transliteration of *zīj*, the Arabic term for astronomical tables. Thus, the Islamic Observatory of the Yuan was in possession of at least 48 volumes of Arabic-language astronomical tables. Moreover, from this we may conclude that the Near Eastern astronomers working at the Islamic Observatory very likely referenced these tables when performing astronomical calculations.

However, despite the extent to which Islamic astronomers were employed in China, the Yuan court neither encouraged exchange between Arab and Chinese counterparts nor organized the translation of Arabic works on

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[3] According to the *Yuanshi* 元史, the Imperial Secretariat was established in 1272 to "collect the books of past dynasties and gather together *yin-yang* and banned books" 掌歷代圖籍，并陰陽禁書 (*Yuanshi*, 90.20).

[4] Zhamaluding, whose name is also written as 札馬魯丁, 扎馬剌丁, and 札馬剌丁, was a Yuan-era astronomer of Persian descent.

[5] There have been many studies of this list, which have drawn connections between, for example, *Wuhulie* 兀忽列 and 'Euclid,' *Handaxiya* 罕荅昔牙 and a Arabic word for 'geometry,' *Maizhesi* 麥者思 and *Almagest*, and *Mataheli* 麻塔合立 and Kūšyār Ibn Labbān's *Madkhal* (an abbreviation of the Arabic title of *Introduction to Astrology*). For a translation of the *Introduction to Astrology*, see Yano Michio (1997).

astronomy.[6] The preface of the *Tianwen shu* 天文書 (*Astronomy*, published in 1383) records that:

> 自洪武初大將軍平元都，收其圖籍……其間西域書數百冊，言殊字異，無能知者。
>
> From the pacification of the Yuan capital by the Great General [Xu Da 徐達 (1332-1385)] at the beginning of the Hongwu reign-period (1368-1398) were captured its books… among them several hundred volumes of books from the Western Regions, but since they were written in different languages, no one could understand a word of them (*Tianwen shu*, 1.1a).

Some of these captured books probably included those enumerated in the *Mishujian zhi*, and the fact that "no one could understand a word of them" suggests that, prior to the Ming dynasty (1368-1644), Arabic books and the mathematical tables in them would have been the purview of only a small number of Near Eastern astronomers working at the Yuan observatories.

Upon founding the Ming dynasty, Zhu Yuanzhang 朱元璋 (1328-1398; r. 1368-1398) immediately acted to retain the Islamic astronomers of the Yuan observatory, whom he transferred to the Huihui counterpart of the Chinese Astronomical Bureau (*Qintianjian* 欽天監; lit. 'Bureau for the Administration of the Heaven') in the new capital at Nanjing. Edicts in the winter of 1368 and summer of the following year mention a transfer of twenty-five personnel, including the former Directors Heidi'er 黑的兒 and Adula 阿都刺, their Assistant Dieliyueshi 迭里月實, and Officer for Calendar-making Zheng Ali 鄭阿里.[7] In his decree appointing Adula the assistant director of the new Huihui Astronomical Bureau, the emperor Zhu Yuanzhang comments that:

> 天文之學，其出於西域者，約而能精。雖其術不與中國古法同，然以其多驗，故近代多用之。
>
> The knowledge of astronomy that comes from the western (Islamic) regions is concise and accurate. Although its methods differ from ancient Chinese ones, they have

[6] Sivin (2011), p. 78, explains that "Khubilai (1215-1294) 忽必烈 was a great enthusiast of astrology and divination. He liked to have separate divinations using different systems, so that he could make the choice between them himself. Khubilai preserved his diverse subjects from many ethnic groups from exchanging information with each other. Of course, he did not want them to join forces against his rule. But just as important, he wanted to choose himself from many possibilities that more than one system of astronomy presented. He preferred to keep knowledge separate, by preventing cooperation and exchange between Islamic and Chinese astronomers."

[7] *Ming Taizu shilu* 明太祖實錄, 41.2.

> proven reliable and have, for that reason, seen frequent use in recent times.[8]

This comment reflects not only the emperor's understanding of the characteristics and differences of Arabic astronomy but the extent of its adoption prior to the Ming.

With the strong support of Zhu Yuanzhang, it was at this point that the reconstituted bureau's work of translating Arabic-language works on astronomy/astrology began. The first was the *Tianwen shu* of 1383, a translation of Kūšyār Ibn Labbān's (Ch. Kuoshiyaer 闊識牙耳; c. 961-1029) *al-Madkhal fī Sinā at Ahkām al-Nujūm* (*Introduction to Astrology*). After the completion of the *Tianwen shu*, the emperor further commissioned a translation of the *Huihui lifa* 回回曆法 (The Huihui Astronomical System), a work appended with a standard set of Arabic astronomical tables and a user's guide with instructions for the calculation of eclipses as well as solar, lunar, and planetary positions.[9] What is more, the emperor even ordered the director of the Astronomical Bureau, Yuan Tong 元統 (fl. 1380s), to begin work to synthesize the two traditions. As a result, Yuan presided over the compilation of *Weidu taiyang tongjing* 緯度太陽通徑 (Comprehensive Guide to the Islamic Method for the Position of the Sun)—a book introducing how to convert calculations from the section of the *Huihui lifa* devoted to solar motion from the Islamic to Chinese calendar as well as how to compute solar ephemerides.[10]

Of these, it has been the translation and publication of the *Huihui lifa* that has received the most attention, eliciting discussion from scholars like Yabuuti Kiyosi 藪內清, Chen Jiujin 陳久金, Yano Michio 矢野道雄, Benno van Dalen, and Shi Yunli 石雲里.[11] In recent years, with the discovery of new sources for the *Weidu taiyang tongjing*, more and more details have come to light supporting the fact that the earliest Chinese edition of the *Huihui lifa* was indeed that completed by experts of the Huihui and Chinese Astronomical Bureaus in the Hongwu reign-period (1368-1398). According to the preface of the *Weidu taiyang tongjing*:

> 洪武乙丑冬十一月欽蒙聖意念玆，慾合而為一，以成一代之曆制。受命選春官正張輔，秋官正成著，冬官正侯政就學與回回曆官，越三年有成。既得其傳，備書來歸。

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[8] 'Adula chu Huihui sitianjian shaojian gao' 阿都刺除回回司天少監誥, in *Ming jingshi wenbian* 明經世文編, 4.13.

[9] Note that the 'Huihui astronomical system' (*Huihui lifa*) was an official astronomical system that the Ming dynasty implemented alongside the Chinese Datong astronomical system (*Datong li* 大統曆), while the eponymously titled book, *Huihui lifa*, was an introduction to the said system.

[10] See Shi Yunli 石雲里 and Wei Tao 魏弢 (2009), pp. 31-45.

[11] Yabuuti (1997); Chen Jiujin (1996); Yano Michio (1999), (2002); Van Dalen (1999), (2002a), (2002b); Shi and Wei (2009).

> In month eleven, in the winter of year *yichou* of the Hongwu reign-period (1385), the emperor directed his sagacious attention to the matter and expressed his intent to synthesize [the two traditions] to achieve an astronomical production of a generation. An order came down selecting Director of the Spring Office Zhang Fu, Director of the Autumn Office Cheng Zhu, and Director of the Winter Office Hou Zheng to study with the Huihui astronomical officials. They completed their studies over the course of three years, and after having been inducted into their tradition, they completed the book and returned (*Weidu taiyang tongjing*, 1.1a).

Thus we see that, at the request of Zhu Yuanzhang, Director of the Astronomical Bureau Yuan Tong selected several Chinese astronomers to study the from their Islamic counterparts and that it was after three years' study that they completed their translation work. Confirming that that Yuan Tong, et al. began their translation of the *Huihui lifa* in the year 1385, Bei Lin 貝琳 (d. 1490) recorded in the colophon to his edition of the *Huihui lifa* that:

> 洪武十八年遠夷歸化，獻土盤曆法，預推六曜干犯，名曰經緯度。時曆官元統去土盤，譯為漢算，而書始行乎中國。

> In the eighteenth year of the Hongwu reign-period (1385), *yi*-foreigners[12] from afar came to pledge their allegiance, submitting in tribute a *Tupan*[13] 土盤 astronomical system, which could predict the encroachments of the six luminaries (the moon and the five planets), and its name was 'Jingweidu' (the longitude and latitude method). At the time, Director Yuan Tong translated the *Tupan* into Chinese computation, and the book then began to circulate in China (*Huihui lifa*, 1.32b).

Though Zhu Yuanzhang had at first hoped to synthesize the Arabic and Chinese traditions of astronomy to meet the needs of astrology and eclipse prediction, the differences between them proved so great that the project was ultimately abandoned.[14] The strengths of Islamic astronomy alone, however, were sufficient to secure it a place alongside the Datong astronomical system (*Datong li* 大統曆) for almost three hundred years. The *Huihui lifa* contains several dozen tables—tables for the mean ecliptic motion of the sun, moon, and planets, correction tables for the true position, as well as various parallax

[12] The "*yi*-foreigners" or *yi* 夷 in Chinese is an ancient term for foreign country or foreigners.

[13] The "Tupan" is believed to be a calculation method with sand that had been used in Arabic world and in India for centuries.

[14] On Zhu Yuanzhang's enthusiasm towards astrology, see Li Liang 李亮 (2011), pp. 132-144.

correction tables for eclipse calculation, etc.—as well as instructions for how to use these tables in the calculation. With these, one cannot only predict the position of the sun, moon, and planets at any given instant, but also calculate the instant and magnitude of eclipses. Combined with the *Huihui lifa*'s fixed star catalog, these could even have been used to calculate lunar and planetary 'encroachments' (*lingfan* 淩犯; the passing of the moon or planets through an asterism) on some 277 stars near the ecliptic—something that traditional Chinese astronomy was never able to realize. I have found in my research that, in addition to addressing the *Datong li*'s inability to calculate 'encroachments,' the *Huihui lifa* also produces superior predictions of eclipse magnitudes—both thanks to the accuracy of its geometrical models and astronomical tables.[15]

Methodology and Sources

The Goals and Methodology of this Paper

There are various editions of the *Huihui lifa* and related works surviving from the fourteenth to eighteenth centuries. While the *Huihui lifa* saw official adoption for several hundred years under the Ming, the differences in tabular layouts and usages between editions have yet to receive much attention. There are to date numerous studies of the *Huihui lifa* and its tables; however, because the contents of the *Huihui lifa* are largely stable across editions, scholars generally neglect differences of tabular layout, simply treating the *Huihui lifa* as a monolithic work that went through a long historical course of editing and reediting. Why were more than ten versions of the *Huihui lifa* compiled in different periods? Why are there differences in layout and writing style between tables in these works when their contents are basically the same? Do these differences reflect changes in the use of the *Huihui lifa* over time? This article is an attempt to explore the issues of the editorial objective, readership, and use of *Huihui lifa* works through the comparative analysis of tabular layout.

It was over the long course of the Huihui astronomical system's implementation that Arabic, then European, astronomy was transmitted to China. At different times, the *Huihui lifa* tables were thus influenced by the respective astronomical traditions of China, Islam, and Europe, such that changes in the tabular layout may in a sense reflect the Chinese adaptation and adoption of foreign astronomical knowledge. Furthermore, because differences in tabular layout bear certain marks of their time, a diachronic analysis

[15] Li Liang, Lü Linfeng 呂凌峰 and Shi Yunli 石雲里 (2011); Li Liang (2011), pp. 85-94.

of these tables may also help us better understand their historical development—something that may even lead us in the future to the development of a typological chronology for the purposes of dating astronomical tables.

Sources for the Huihui Astronomical System

In terms of primary sources, this article examines astronomical tables from works of Arab astronomy that circulated in China, including Arabic manuscripts in use prior to the Ming and various recensions of the *Huihui lifa* as translated into Chinese (see Table 1).[16]

[16] On *Huihui lifa* editions, see Li Liang (2011), pp. 48-66.

Table 1. Different *Huihui lifa* works

no.	Text	Abbr.	Compiler	Date
1	*Sanjufini Zīj*	-	al-Sanjufīni	1366
2	MS C 2460	-	-	c.1380s
3	*Huihui lifa* (Hongwu ed.) 洪武本《回回曆法》	*HW-HHLF*	Yuan Tong 元統	c.1385
4	*Xiyu lifa tongjing* 西域曆法通徑	*XYLFTJ*	Liu Xin 劉信	c.1430s
5	*Qizheng suan waipian* 七政算外篇	*QZSWP*	Yi Sunji 李純之 & Kim Tam 金淡	1444
6	*Huihui lifa* (Bei Lin ed.) 貝琳本《回回曆法》	*BL-HHLF*	Bei Lin 貝琳	1477 (rpt. 1569)
7	*Lifa xinshu* 曆法新書	*LFXS*	Yuan Huang 袁黃	c.1570s
8	*Huihui lifa* (Xue Fengzuo ed.) 薛鳳祚輯本《回回曆法》	*XFZ-HHLF*	Xue Fengzuo 薛鳳祚	1664
9	*Huihui lifa* (Nanjing Lib. ed.) 南圖本《回回曆法》	*NJ-HHLF*	Mei Wending 梅文鼎[17]	c.1710
10	*Huihui lifa* in *Mingshigao* 明史稿《回回曆法》	*MSG-HHLF*	-	1723
11	*Huihui lifa* in *Mingshi* 明史《回回曆法》	*MS-HHLF*	-	1739
12	*Qizheng tuibu* 七政推步	*QZTB*	-	c.1780

According to van Dalen and Yano Michio, the Islamic astronomical tables that came to circulate in China can be traced back to two Arabic *zīj* manuscripts that were later procured from China sometime in the nineteenth century. The first is the *Sanjufini Zīj* (Arabic 6040), which is believed to have been copied in 1366 by the otherwise unknown astronomer al-Sanjufīni for the Mongol viceroy of Tibet. Now preserved at the Bibliothèque Nationale de France, this collection of tables includes a librarian's annotations in Chinese, Tibetan transcriptions of month names, and translations of table headings into Mongolian.[18] The second is MS C 2460, an anonymous manuscript of Arabic astronomical tables now preserved at the Institute of Oriental Studies in St. Petersburg. Van Dalen argues that the former, which is quite atypical of Arabic astronomical tables, exhibits significant parallels with the

[17] Note that while my researches have led me to the conclusion that *NJ-HHLF* should be attributed to Mei Wending, it has also been attributed to Huang Zongxi 黄宗羲 in Tao Peipei 陶培培 (2003), pp. 117-127.

[18] See Franke (1988), pp. 95-118.

Huihui lifa in terms of constants for planetary motion.[19] While the two are distinct works, he concludes that they probably derive from a common source. He then goes on to conjecture that the former was connected with Kublai Khan's Islamic Observatory in Beijing, and that MS C 2460 was one of the sources used in the Chinese translation of the *Huihui lifa*.[20]

In addition to these Arabic manuscripts, this article is also concerned with the comparison of various *Huihui lifa* works. Though the first edition of the Hongwu reign-period translation (*HW-HHLF*) is now lost, there are more than ten works from subsequent centuries compiled therefrom that still extant. In order, Liu Xin's 劉信 (d. 1449) *Xiyu lifa tongjing* 西域曆法通徑 (Comprehensive Guide to the Astronomy of the Western Regions) has the largest tables. Yi Sunji 李純之 (1406-1465) and Kim Tam's 金淡 (fl. 1442) *Qizheng suan waipian* 七政算外篇 (Calculations of the Seven Regulators, the Outer Chapters) in 5 volumes was compiled from the *HW-HHLF* during the reign of King Sejong 世宗 (1418–1450) of the Chosŏn dynasty and, as the earliest such work extant, is an invaluable resource for the study of early editions of the *Huihui lifa*.[21] The Bei Lin 貝琳 (d. 1490) edition is a 1477 recension of the *HW-HHLF* attributed to Bei Lin, the assistant director of the Nanjing Astronomical Bureau. Yuan Huang's 袁黃 (1533-1606) *Lifa xinshu* 曆法新書 (New Book of Mathematical Astronomy) is a late-Ming synthesis of the Huihui and Datong astronomical systems. The *Huihui lifa* saw numerous revisions under the Qing dynasty as well, e.g. the Xue Fengzuo 薛鳳祚 (1599-1680) edition, whose contents are almost identical to *BL-HHLF* except for somewhat large adjustments to tabular layout and Xue's addition of sample problems that he had personally worked out. Other Qing editions include the Nanjing Library edition, and the editions preserved in the *Mingshi gao* 明史稿 (Draft of Ming History; published 1723) and *Mingshi* 明史 (History of the Ming; published 1739) as part of the compilation of the official histories—as the *Mingshi* edition is based on the *Mingshi gao* edition which is in turn based on the Nanjing Library edition, we might collectively refer to them as the '*Mingshi*-series.' The *Qizheng tuibu* 七政推步 (Calculation of the Seven Regulators) is identical in contents to the *BL-HHLF*, its name simply changed in the 1780s upon its inclusion in the *Siku quanshu* 四庫全書 (Complete Library of the Four Treasuries). While these works are basically identical in terms of method and content, many of their tables have been rearranged such that there exist between them significant differences in layout and application.

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[19] Van Dalen points out that the setup of various tables in the *Huihui lifa* and the *Sanjufini Zīj* is different from what have found in other *Zīj*es.

[20] Van Dalen (2002), pp. 19-31.

[21] Shi Yunli (2003), pp. 25-60.

Parallax Correction Tables

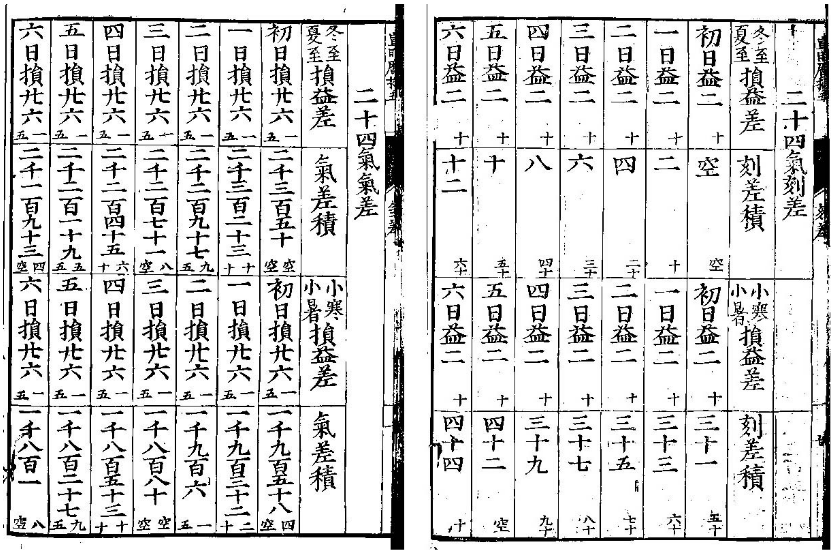
Due to substantial differences in theory, function and approach to parallax, the layout of parallax correction tables in the Chinese and Arab traditions of astronomy is completely different. As such, parallax correction tables can be used as an unequivocal indication of a text's origin in one or the other tradition.

The traditional Chinese methods of parallax correction—*qicha* 氣差 (E-W correction), *kecha* 刻差 (N-S correction), and *shicha* 時差 (time correction)—tend to rely exclusively on *formulae* wherein each step of calculation is described in prose. This is the case, for example, with the Huihui astronomical system's Chinese counterpart, the Datong system. Although we know that other Chinese astronomical systems did incorporate parallax tables, they are nowhere to be found in extant texts like the 'Lü li zhi' 律曆志 (Treatises on Harmonics and Astronomy) of the dynastic histories. In fact, the only precedent for indigenous parallax tables are the 'Ershisi qi qicha' 二十四氣氣差 (Twenty-four *Qi Qicha*) and 'Ershisi qi kecha' 二十四氣刻差 (Twenty-four *Qi Kecha*) tables that I have recently discovered in a Japanese edition of the Xuanming astronomical system (*Xuanming li* 宣明曆) held at Waseda University (see fig. 1). Attributed to Andō Yūeki 安藤有益 (1624–1708), the edition in question was printed in 1654.[22] However, its preface mentions that, with the exception of the addition of several diagrams, other contents like tables closely follow the original book—the *Xuanming li* that was transmitted from China (where it saw official use from 822-c. 892)[23] to Japan in the ninth century, where it would be implemented for 823 years from AD 862 to 1685. From these tables, we can tell that traditional Chinese parallax tables are arranged around the twenty-four *qi* of the tropical year with corrections for subsequent days of argument into each *qi*.

[22] See Fujii Yasuo 藤井康生 (2005), pp. 89-102.

[23] Note that the *Song shi* 宋史 'Yiwen zhi' 藝文志 records a *Xuanming li* with two volumes of *lijing* 曆經 'canon' and eight volumes of *licheng* 立成 'tables.' The 'Lü li zhi' edition of the *Xuanming li*, however, only preserves the former.

Figure 1. Waseda *Xuanming li* parallax correction tables



二十四氣氣差

	損益差	氣差積
冬至夏至		
初日	損廿六 五一	二千三百五十 空空
一日	損廿六 五一	二千三百二十三 十十
二日	損廿六 五一	二千二百九十七 五九
三日	損廿六 五一	二千二百七十一 空八
四日	損廿六 五一	二千二百四十五 十六
五日	損廿六 五一	二千二百一十九 五五
六日	損廿六 五一	二千一百九十三 空四
小寒小暑		
初日	損廿六 五一	一千九百五十八 空四
一日	損廿六 五一	一千九百三十二 十二
二日	損廿六 五一	一千九百六 五一
三日	損廿六 五一	一千八百八十 空空
四日	損廿六 五一	一千八百五十三 十十
五日	損廿六 五一	一千八百二十七 五九
六日	損廿六 五一	一千八百一 空八

二十四氣刻差

	損益差	刻差積
冬至夏至		
初日	益二 十	空 空
一日	益二 十	二 十
二日	益二 十	四 二十
三日	益二 十	六 三十
四日	益二 十	八 四十
五日	益二 十	十 五十
六日	益二 十	十二 六十
小寒小暑		
初日	益二 十	三十一 五十
一日	益二 十	三十三 六十
二日	益二 十	三十五 七十
三日	益二 十	三十七 八十
四日	益二 十	三十九 九十
五日	益二 十	四十二 空
六日	益二 十	四十四 十

NOTE: ‘Ershisi qi qicha’ 二十四氣氣差 (left) and ‘Ershisi qi kecha’ 二十四氣刻差 (right).

Like traditional works of Arabic astronomy, the *Huihui lifa* divides parallax into longitudinal and latitudinal components, for which it borrows the Chinese terms *dongxicha* 東西差 ‘E-W equation’ and *nanbeicha* 南北差 ‘N-S equation,’ respectively. The *dongxicha* directly influences apparent lunar longitude and, thus, the instant of maximum apparent solar eclipse, while the *nanbeicha* directly influences apparent lunar latitude and, thus, the magnitude of a solar eclipse. In addition, the *Huihui lifa* provides a *shicha* 時差 ‘time equation,’ which is the *dongxicha* divided by the difference between lunar and solar motion when the moon is at the apogee of its epicycle—a concrete manifestation of the *spatial* parallax correction in the form of a *temporal* correction.[24] Comparison of the parallax correction tables between the *Huihui lifa* and Arabic manuscripts reveals that their data are identical and their layouts are very similar.

In terms of the layout, *BL-HHLF* and *QZSWP* offer double-argument tables (fig. 4) that are completely identical to the *Sanjufini Zīj* and MS C 2460 (fig. 2 and 3). The columns at the far right and left of each table are the names and numbers of the zodiacal signs, each representing the beginning of said sign such that “Cancer, sign three” 巨蟹三宫 indicates 90° longitude, and “Libra, sign six” 天秤六宫 indicates 180°. The rows at the top and bottom of

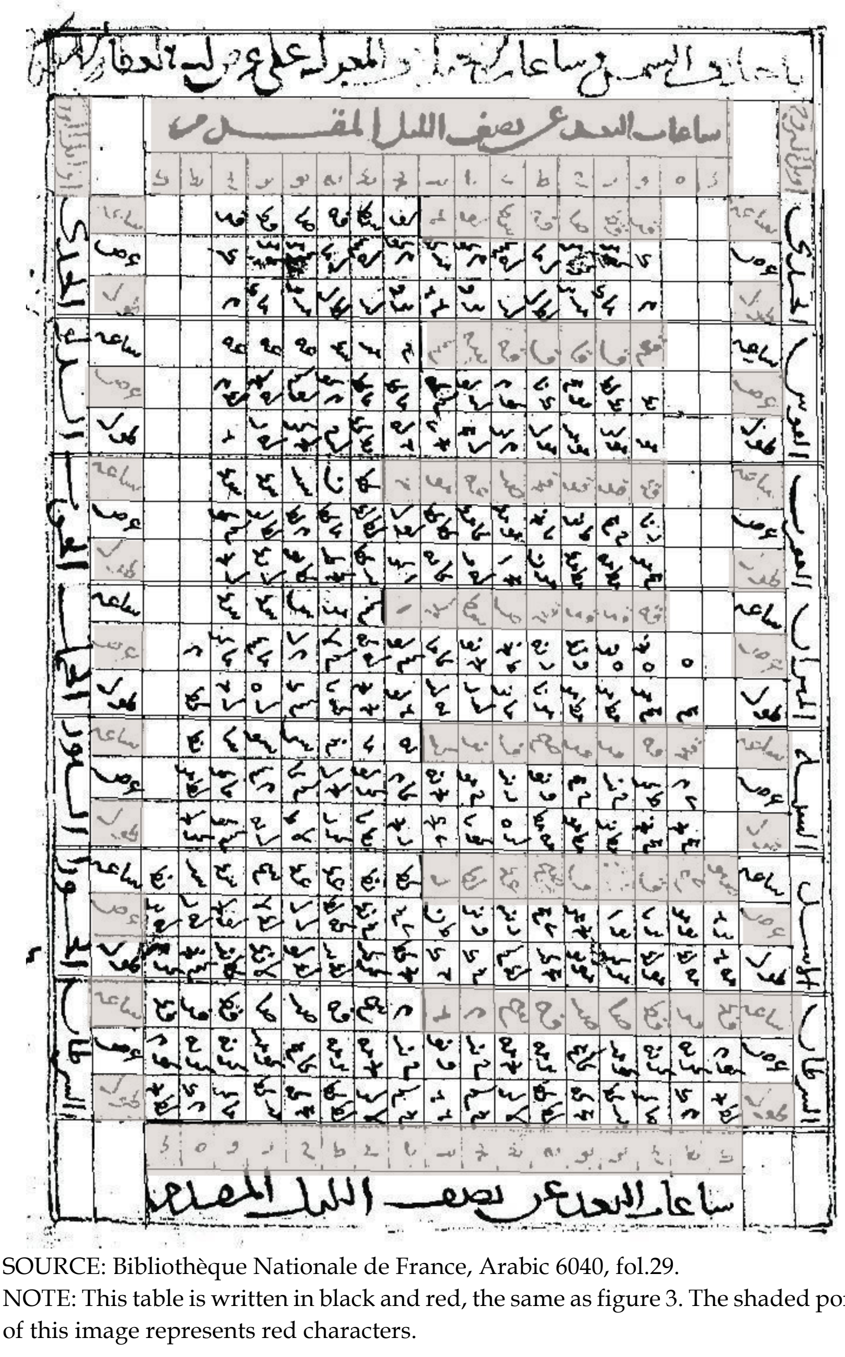
[24] Tang Quan 唐泉 (2007), pp. 114-122.

each table provide the argument of time, which is given in one-hour intervals from 04:00-20:00. To find the parallax correction corresponding to a specific longitude and hour, one simply finds the value located where the appropriate row and column meet. There the three corrections are respectively marked *shi* 時 'time,' *wei* 緯 'latitude,' and *jing* 經 'longitude' (i.e. *shicha*, *nanbeicha*, and *dongxicha*, respectively). The direction in which one reads the table and the sign (+/−) of the correction are determined by the object's position along the ecliptic. For example, the *BL-HHLF* provides the following instructions:

> 視其日合朔時太陽度在左七宮，其時差黑字者減，白字者加，在右七宮白字者減，黑字者加。
>
> If the solar position at the time of syzygy is among the left seven signs, find its *shicha*, the black characters (numbers) are negative and the white ones are positive; if in the right seven signs, the white ones are negative and the black ones are positive (*Huihui lifa*, 1.21a).

The *Huihui lifa*'s method of using black and white characters to indicate positive and negative also originates from Arabic astronomical tables, which use black and red ink, respectively, to the same effect. MS C 2460 is particularly interesting in this regard: though the table is completely in Arabic, in the bottom left and right corners of the table are written "red positive" (*hongjia* 紅加) and "red negative" (*hongjian* 紅減), respectively, indicating in Chinese that the red numbers of the left seven signs should be positive numbers and vice versa.

Figure 2. ***Sanjufīni Zīj*** **parallax correction table**

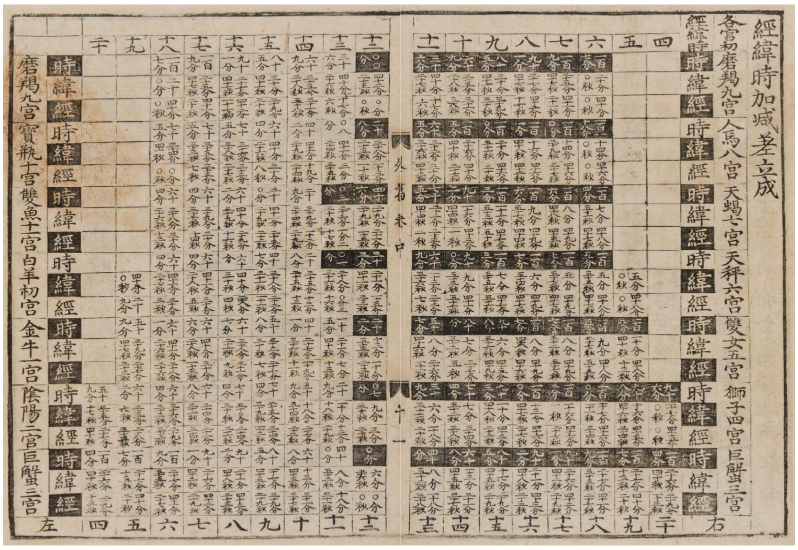


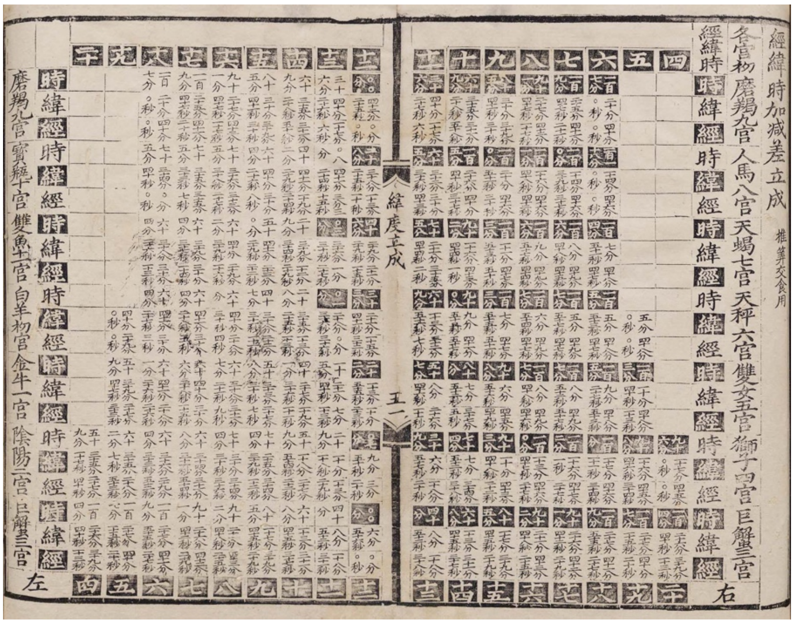
SOURCE: Bibliothèque Nationale de France, Arabic 6040, fol.29.
NOTE: This table is written in black and red, the same as figure 3. The shaded portion of this image represents red characters.

Figure 3. ***MS C 2460*** **parallax correction table**

SOURCE: Institute of Oriental Studies, St. Petersburg, MS C 2460 titled '24 folios of Astronomical Tables.'

Figure 4. *QZSWP* and *BL-HHLF* parallax correction table ('Jingweishi jiajian licheng' 經緯時加減立成)





SOURCE: *QZSWP* (top) is preserved in Kyujanggak Library, Seoul National University. *BL-HHLF* (bottom) is preserved in the Interior Department of the National Archives of Japan.

It is evident that *BL-HHLF* and *QZSWP* have absorbed numerous characteristics from Arabic tables, e.g. their symmetrical layout and the use of color to distinguish positive and negative numbers. However, parallax tables in later *Huihui lifa* works exhibit a number of adjustments. For example, the *MS-HHLF* tells us that:

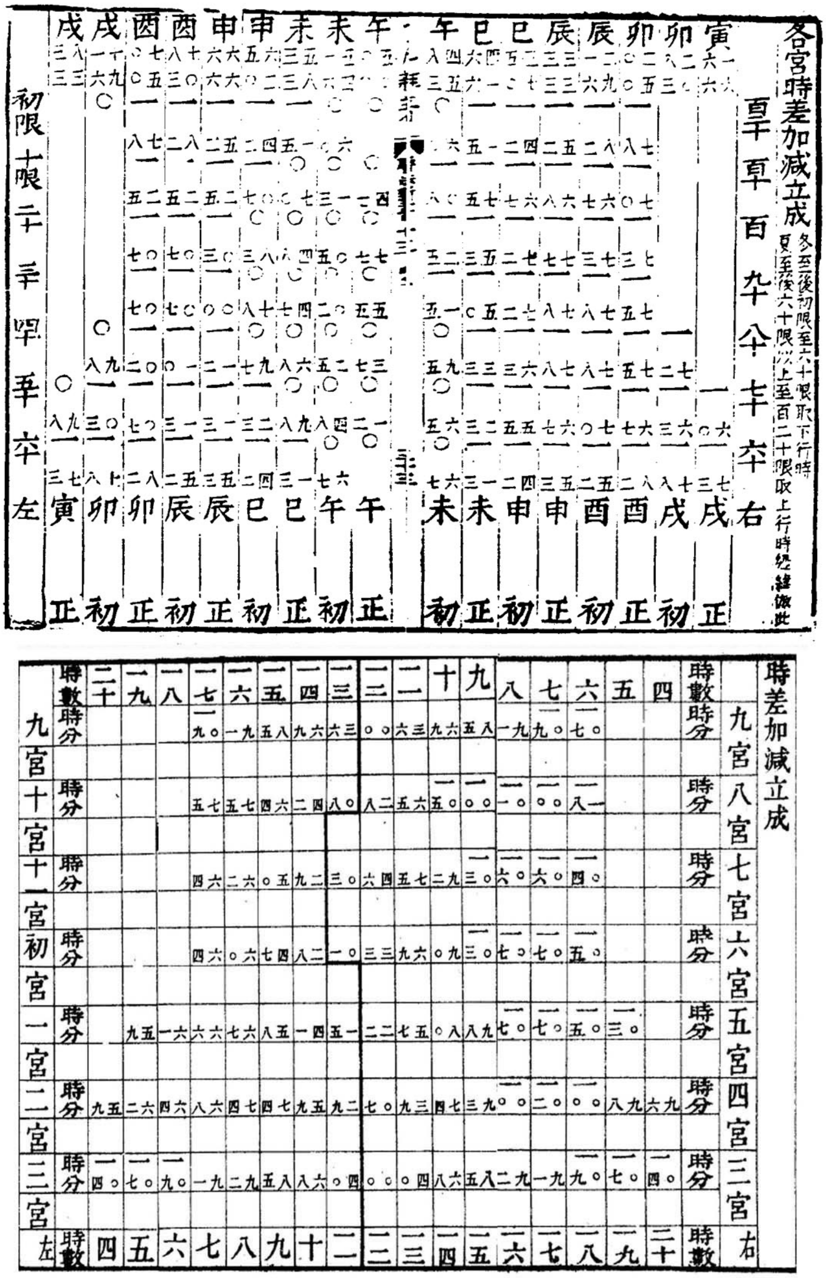
> 經緯時三差本合一立成，今因太密，將時差分另列以立成。
>
> The longitude, latitude, and time equations were originally listed together in a single table. Because this gets too crowded, we now split the time equation off into a separate table (*Mingshi*, 39.25a).

In addition, there is also a corresponding adjustment to layout and the expression of data. The *LFXS* tables, for example, replace the sexagesimal values of the original table with centesimal ones (see fig. 5), the meaning of which will be addressed below. Furthermore, the *Mingshi*-series abandon the color-coding method in favor of dividing lines (see fig. 5).

The use of a dividing line originates from the double-argument 'Huangdao nanbeiwei licheng' 黃道南北緯立成 (Planetary latitude tables) of *Huihui lifa* works.[25] In addition to specific values of latitude, these tables must distinguish whether those values lie north or south of the ecliptic. *Huihui lifa* works achieve this by use of a dividing line. For example, *QZSWP* uses a red line marked 'ecliptic' (*huangdao* 黃道) to divide its tables into two sections corresponding to zones south and north of the ecliptic (see fig. 7). Likewise, *BL-HHLF* uses a black double-line to the same effect (see fig. 6). We shall refer to this method of dividing table contents into multiple zones by means of lines as 'the dividing line method.'

[25] *Licheng* 立成 is a term that appears after the Tang dynasty referring to a kind of 'handy table' or 'pick-up table' used to reduce the burden of calculation through polynomial interpolation and later extended to denote mathematical tables in general. It is only after the Ming that *biao* 表 comes to mean 'table,' eventually replacing the term *licheng*. See Li Liang (forthcoming).

Figure 5. ***LFXS*** **and** ***MS-HHLF*** **parallax correction table (‘Shicha jiajian licheng’ 時差加減立成)**


各宮時差加減立成

冬至後初限至六十限取下行時 夏至後六十限以上至百二十限取上行時

戌 戌 酉 酉 申 申 未 未 午 午 巳 巳 辰 辰 卯 卯 寅

寅 卯 卯 辰 辰 巳 巳 午 午 未 未 申 申 酉 酉 戌 戌

正 初 正 初 正 初 正 初 正 初 正 初 正 初 正 初 正

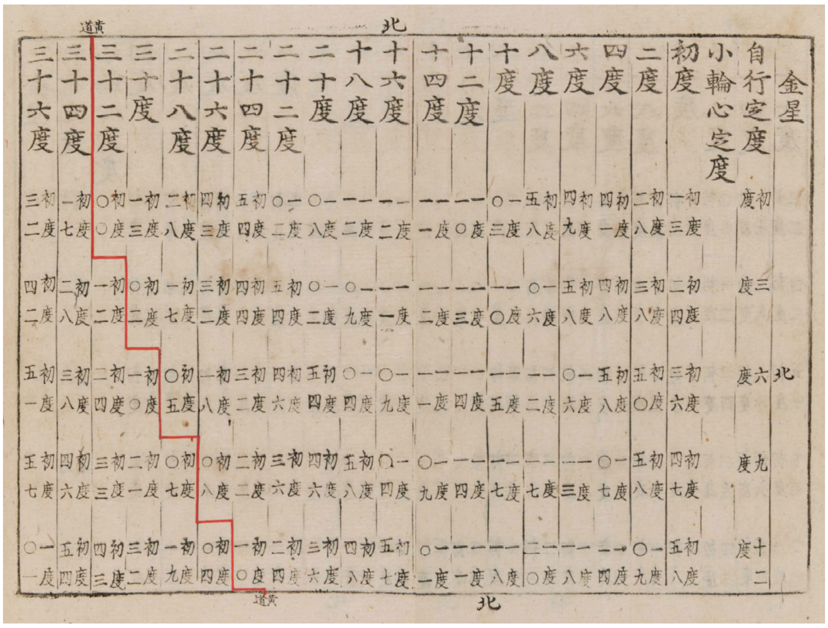
時差加減立成

	時數	二十	一九	一八	一七	一六	一五	一四	一三	一二	一一	十	九	八	七	六	五	四	時數	
九宮	時分				一 九〇	一九	五八	九六	六三	〇〇	六三	九六	五八	一九	一 九〇	一 七〇			時分	九宮
十宮	時分				五七	五七	四六	二四	八〇	八二	五六	一 五〇	一 〇〇	一 一〇	一 〇〇	一 八一			時分	八宮
十一宮	時分				四六	二六	〇五	九二	三〇	六四	五七	二九	一 三〇	一 六〇	一 六〇	一 四〇			時分	七宮
初宮	時分				四六	〇六	七四	八二	一〇	三三	九六	〇九	一 三〇	一 七〇	一 七〇	一 五〇			時分	六宮
一宮	時分		九五	一六	六六	七六	八五	一四	五一	二二	七五	〇八	八九	一 七〇	一 七〇	一 五〇	一 三〇		時分	五宮
二宮	時分	九五	二六	四六	八六	四七	四七	九五	九二	七〇	九三	四七	三九	一 〇〇	一 二〇	一 〇〇	八九	六九	時分	四宮
三宮	時分	一 四〇	一 七〇	一 九〇	一九	二九	五八	八六	〇四	〇〇	〇四	八六	五八	二九	一九	一 九〇	一 七〇	一 四〇	時分	三宮
左	時數	四	五	六	七	八	九	十	一一	一二	一三	一四	一五	一六	一七	一八	一九	二十	時數	右

Figure 6. ***BL-HHLF*** **latitude table for Venus**
('Jinxing nanbei weidu licheng' 金星南北緯度立成)

SOURCE: Interior Department of the National Archives of Japan.

Figure 7. *QZSWP* latitude table for Venus (‘Jinxing nanbei weidu licheng’ 金星南北緯度立成)



黄道 北

金星	自行定度	小輪心定度	初度	二度	四度	六度	八度	十度	十二度	十四度	十六度	十八度	二十度	二十二度	二十四度	二十六度	二十八度	三十度	三十二度	三十四度	三十六度
	初度		一初 三度	二初 八度	四初 一度	四初 九度	五初 八度	○一 三度	一一 ○度	一一 一度	一一 二度	一一 二度	○一 八度	○一 二度	五初 四度	四初 三度	二初 八度	一初 三度	○初 ○度	一初 七度	三初 二度
	三度		二初 四度	三初 八度	四初 八度	五初 八度	○一 六度	一一 ○度	一一 三度	一一 二度	一一 一度	○一 九度	○一 二度	五初 四度	四初 四度	三初 二度	一初 七度	○初 二度	一初 二度	二初 八度	四初 二度
北	六度		三初 六度	五初 ○度	五初 八度	○一 六度	一一 二度	一一 五度	一一 四度	一一 一度	○一 九度	○一 四度	五初 四度	四初 六度	三初 二度	一初 八度	○初 五度	一初 ○度	二初 四度	三初 八度	五初 一度
	九度		四初 七度	五初 八度	○一 七度	一一 三度	一一 七度	一一 七度	一一 四度	○一 九度	○一 四度	五初 八度	四初 六度	三初 六度	二初 二度	○初 八度	○初 七度	二初 一度	三初 三度	四初 六度	五初 七度
	十二度		五初 八度	○一 九度	一一 四度	一一 八度	二一 ○度	一一 八度	一一 一度	○一 一度	五初 七度	四初 八度	三初 六度	二初 四度	一初 ○度	○初 四度	一初 九度	三初 二度	四初 三度	五初 四度	○一 一度

黄道 北

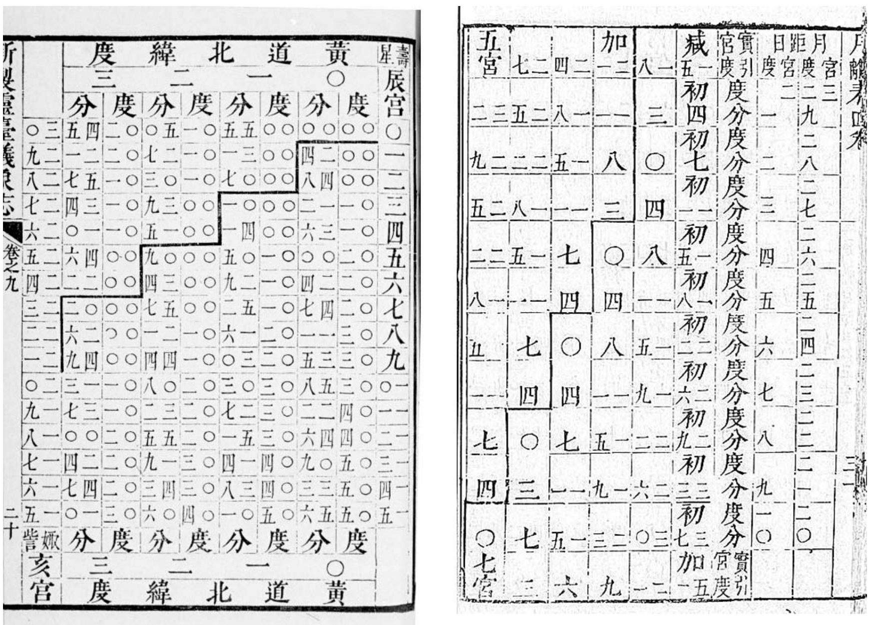
SOURCE: Kyujanggak Library, Seoul National University.

While the dividing line method enjoys wide use in *Huihui lifa* planetary latitude tables, it is almost unprecedented in the traditional Chinese astronomical tables that predate them because they do not even offer a method for calculating planetary latitude. Furthermore, whereas this method first appears in *Huihui lifa* to differentiate north/south latitude, it is later extended to the differentiation of positive/negative values. Beginning in the seventeenth century, this method even found its way into works of European astronomy for Chinese consumption. For example, the key to the ‘Dipingyi biao’ 地平儀表 (Horizon instrument table) in Ferdinand Verbiest’s (1623-1688) *Xinzhi lingtai yixiangzhi* 新制靈台儀象志 (Treatise on the Newly Constructed Observatory Instruments) instructs the user that: “When you encounter a bold vertical line, the [values] to the right of the line are degrees south [of the ecliptic], and the [values] to the left of the line are degrees north” 凡遇縱格之粗線，其線上右者，系向南之度，其線上左者，向北之度 (*Xinzhi lingtai yixiangzhi*, 6.4). Verbiest uses this dividing line method throughout the other tables of his book as well (see fig. 8). In another example, the ‘Er san junshu yueli biao’ 二三均數月離表 (Second and third equation table of the moon) in *Xiyang xinfa lishu* 西洋新法曆書 (Treatises on Calendrical

Astronomy according to the New Methods from the Western Ocean) implements the dividing line method to distinguish positive/negative values in a 'rotational symmetry' layout (see fig. 8). According to the key:

> 表右兩直行，上下兩横行，各有宮有度，各有順數，有逆數，凡用右行順數之宮度，則以當上横行順數之宮度。用右行逆數之宮度則以當下横行宮度者。…兩引數縱横相遇為次均數，或上或下，各有加減之號，其中面有曲折線相隔者為變號之界。
>
> The two columns to the right of the table and the rows running above and below it are each possessed of signs and degrees, and each are possessed with numbers running forwards and backwards. Whenever the sign-degree argument belongs to the forward-running numbers, use the sign-degrees listed in the forward-running row above, and vice versa. … Where the column and row of the argument meet is the second equation value. This is sometimes above or below, and each is marked with the sign for addition or subtraction, and the zigzag line that runs through the table acts as the boundary where the sign changes (*Xiyang xinfa lishu*, 34.1a).

Figure 8. *LTYXZ* 'Huangchi eryi biao' 黄赤二儀表 (left) and *XYXFLS* 'Ersan junshu biao' 二三均數月離表 (right)



Be it the "bold line" of the *Xinzhi lingtai yixiangzhi* or the "zigzag line" of the *Xiyang xinfa lishu*, the function is identical to the dividing line of the *Huihui lifa*: the division of table values into either north/south or positive/negative. The case of the latter is also similar to the function of the black and white characters of the *BL-HHLF* and *QZSWP* parallax correction tables introduced above. Thus it is, for example, that the *Mingshi*-series tables are able to convert from black and white characters to dividing lines without complication.

In conclusion, comparison of the parallax correction tables in Arabic and Chinese sources reveals that, with the use of Arabic tables, Chinese astronomers came to fully adopt the organizational principles behind them in their own work. These changes, therefore, present invaluable clues about the process of translation and transmission that Arabic astronomical tables underwent in China. Of course, the switch from black/red to black/white characters demonstrates the sort of contextual entailments and flexible in usage that were at once involved in this process. The black/red characters of the Arabic tables make perfect sense in the context of manuscript transmission, where red writing is both eye-catching and easy to produce. As Chinese editions of the *Huihui lifa* were printed, however, they had to make certain concessions to that medium, e.g. resorting to 'white' characters carved in relief. The adoption of the dividing line method in the later *Mingshi*-series was, we might presume, a further concession aimed at simplifying the process of woodblock production as much as it was for the sake of consistency—consistency *vis-à-vis* the latitude tables.

Tables for Planetary Equation of Center

Huihui lifa works feature dozens of tables each, and while their contents are basically identical, the layout, number-format, and methods of interpolation for tables such as those for solar, lunar, and planetary equation of center vary wildly across the genre. In this section we will examine the case of the 'Jinxing di'er jiajiancha licheng' 金星第二加減差立成 (Second correction table for Venus) to discuss differences between *BL-HHLF*, *XYLFTJ*, *LFXS*, and *MS-HHLF* versions of this table.

Tabular Layout

The 'Jinxing di'er jiajiancha licheng' is a table for looking up one of the corrections the *Huihui lifa* requires the user apply to the mean position of Venus so as to calculate its true position. In terms of layout and use, *BL-HHLF* places the table's title to the top right, the contents of the table are divided into four sections according to the sequence of the zodiacal signs (three signs per section), and the table runs from top to bottom. Each sign includes three values: *jiajiancha* 加減差 (the second correction), *jiajianfen* 加減分 (the interval between second corrections, a value used in interpolation), and *yuanjindu* 遠近度 (data for use in third, rather than second, corrections). At the top of the table is the *zixing dingdu* 自行定度 (the epicyclic definite anomaly) argument, which is given in one-degree intervals from the first to thirtieth degree of each sign (the calculation of fractional angles require linear interpolation) running from right to left, in the traditional direction of Chinese writing (see fig. 9). The table is introduced by a key explaining its use and the appropriate method of interpolation required:

> 求第二加減差
>
> 法曰：視其星自行定度，其宮度入各星第二加減立成，内宮内度下兩取之，得其度分為未定差。其分已下小餘，以本行加減分乘之，滿六十約之為分。視加減差少如後行者加之，多如后行者減之，用加減兩取到未定差，即為所求第二加減差也。
>
> Finding the second correction
>
> Method: look at the planet's *zixing dingdu*—its two arguments in signs and degrees entered into each planet's second correction table—and get the values (*jiajiancha*) for the degrees and minutes as the appropriate unfixed correction (*weidingcha*). Multiply the fractional remainder of its own argument (in degree) by the *jiajianfen*, and convert each sixty (of the result) to a minute. If the *jiajiancha* is smaller than the next one, then add it; and if it is larger, then subtract it. After adding or subtracting this from the *weidingcha*, the result is the second correction that you seek (*Huihui lifa*, 1.6b).

Figure 9. ***BL-HHLF*** **second equation table for Venus ('Jinxing di'er jiajian yuanjin licheng' 金星第二加減遠近立成)**

Argument (Sign / Degree)	Sign 0 Jiajian cha	Sign 0 Jiajian fen	Sign 0 Yuanjin du	Sign 1 Jiajian cha	Sign 1 Jiajian fen	Sign 1 Yuanjin du	Sign 2 Jiajian cha	Sign 2 Jiajian fen	Sign 2 Yuanjin du
0°	0° 0′	26′	0° 0′	12° 22′	25′	0° 16′	24° 22′	23′	0° 33′
1°	0° 26′	25′	0° 1′	12° 47′	25′	0° 16′	24° 45′	22′	0° 34′
2°	0° 51′	24′	0° 1′	13° 12′	24′	0° 17′	25° 07′	23′	0° 35′
3° (A_N)	1° 15′ (D_N)	25′ (I_N)	0° 2′	13° 36′	24′	0° 18′	25° 30′	23′	0° 35′
4° (A_{N+1})	1° 40′ (D_{N+1})	25′	0° 2′	14° 0′	25′	0° 18′	25° 53′	22′	0° 36′
5°	2° 05′	25′	0° 3′	14° 25′	24′	0° 19′	26° 15′	23′	0° 37′
6°	2° 30′	24′	0° 3′	14° 49′	24′	0° 19′	26° 38′	23′	0° 38′
7°	2° 54′	25′	0° 4′	15° 13′	24′	0° 20′	27° 01′	22′	0° 38′

Title of the table

NOTE: In the original table (left), some data for the higher units (degrees) are understood to repeat in case of omission. For example, "one degree and forty minutes" 一度四十分 is written "forty minutes" 四十分, since it follows the entry "one degree and fifteen minutes"一度一十五分 and the "one degree" 一度 need not be repeated. To aid easy comprehension, I have provided a reconstruction of the table's values in modern notation here (right) and in subsequent figures.

The operation of this table is as follows. Let us say that we must find the second correction for a *zixing dingdu* (A) of 3°30′. First, we find that A is located in the sign 0 of the zodiac, and its argument is the integer (A_N) 3° and the remainder (A_R) 30′. So, first we find the entry A_N on the table ("3°" 三度, the entry in the third column from the right) to obtain the three values under the appropriate column for the said sign: the *jiajiancha* (D_N) "1°15′" 一度一十五分, the *jiajianfen* (I_N) "25′" 二十五分 ($I_N = D_{N+1} - D_N$), and the *yuanjindu* (which we omit here). Multiply the remainder A_R by the *jiajianfen* I_N and divide by 60 to obtain the interpolated value I_F ($30' \times 25' = 12'30''$). Then, by the same method find the *jiajiancha* D_{N+1} ("1°40′" 一度四十分) for the entry following A_N, A_{N+1} ("4°" 四度). Compare D_N and D_{N+1}. If D_N is greater than D_{N+1}, then the value of the second correction is $C = D_N - I_F$; if D_N is less than D_{N+1}, then $C = D_N + I_F$. In this case, because D_N (1°15′) is less than D_{N+1} (1°40′), the correction equals 1°27′ 30″ (=1°15′ + 12′30″). Throughout, the table provides sexagesimal values written out in full, e.g. "one degree one-ten and five minutes" 一度一十五分 for 1°15′.

The title of this table in *XYLFTJ* is 'Ding jinxing di'ercha licheng' 定金星第二差立成 (Table for the fixed second correction of Venus). Compared to the tables of the other works, this has the largest dimensions, features a unique arrangement, and is the simplest to use. In terms of layout, each page is divided into two registers, each with five rows: the *ercha* 二差 'second correction' output and four rows beneath it devoted to the *zixing dingdu* arguments for each sign (see fig. 10).

Figure 10. *XYLFTJ* second equation table for Venus ('Ding jinxing di'ercha licheng' 定金星第二差立成)

ercha	*zixing dingdu* arguments				*ercha*	*zixing dingdu* arguments			
	Sign 0	Sign 5	Sign 6	Sign 11		Sign 0	Sign 5	Sign 6	Sign 11
0° 0′	0° 0′			29° 59′	0° 10′	0° 22′	9° 56′	0° 04′	29° 36′
0° 1′	0° 2′			29° 57′	0° 11′	0° 25′			29° 34′
0° 2′	0° 04′	29° 59′	0° 1′	29° 55′	0° 12′	0° 27′	9° 55′	0° 05′	29° 32′
0° 3′	0° 06′			29° 52′	0° 13′	0° 29′			29° 29′
0° 4′	0° 09′			29° 50′	0° 14′	0° 32′			29° 27′
0° 5′	0° 11′	29° 58′	0° 2′	29° 48′	0° 15′	0° 34′	9° 54′	0° 06′	29° 25′
0° 6′	0° 13′			29° 46′	0° 16′	0° 36′			29° 22′
0° 7′	0° 16′	29° 57′	0° 3′	29° 43′	0° 17′	0° 39′	9° 53′	0° 07′	29° 20′
0° 8′	0° 18′			29° 41′	0° 18′	0° 41′			29° 18′
0° 9′	0° 20′			29° 39′	0° 19′	0° 43′	9° 52′	0° 08′	29° 16′

NOTE: In ancient China, blank table cells denote one of two things: either repetition (above) or a value of zero. Here it is the former that is the case.

In contrast to the *BL-HHLF*, the values of this table have been recomputed according to an inverse function[26] such that the four arguments share a single output (see fig. 11) and that the second correction is given in one-arc minute intervals. While the reason behind this is not entirely clear, it is certainly the case that such a table would prove simpler to use in practice, as evidenced by the brevity of the table's introduction:

[26] The reason of this adjustment needs further research.

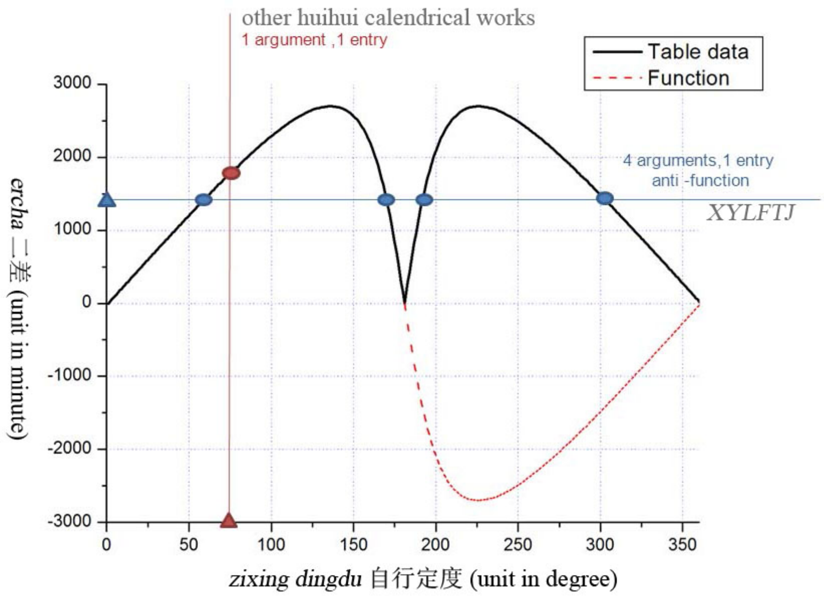
求金星第二

視金星自行定宮度全分，其宮度分入金星第二差立成內相同宮度分，取上第二差，挨而錄之，即為金星第二差也。

Finding the second [correction] for Venus

Look at the sign and degrees with their integral and fractionary parts in the Venus' *zixing dingdu*, then get the second correction from the corresponding *zixing dingdu* of said sign, degree, and minute in the upper part of 'Table for the second correction of Venus.' Write this down, and this is your second correction for Venus (*Xiyu lifa tongjing*, 11.1a)

Figure 11. Curve fitting the *XYLFTJ* second equation table for Venus



NOTE: This curve is drawn according to the data in the *XYLFTJ* second correction table for Venus. The solid line is fit to the table data—which is all positive—while the dotted line represents the trigonometric function for the true value of correction. This table appears in other *Huihui lifa* works as a one-argument table, but the *XYLFTJ* is unique in its use of the inverse function in the compilation of its table, providing four arguments with a single output.

The obvious benefit of this table's dimensions and the compact interval between values is that they obviate the need for interpolation. This allows the user to simply look up the nearest value to that sought from the lower four rows and read the corresponding output from the upper row.

In the terms number-format, this table uses sexagesimal fractions. Furthermore, it marks the upper integer value of degrees with the character *du* 度 (degree) while omitting *fen* 分 (minute) from the lower fractional unit, and the number of minutes using a place value notation, thus writing "one degree two eight minutes" 一度二八 for 1°28′.

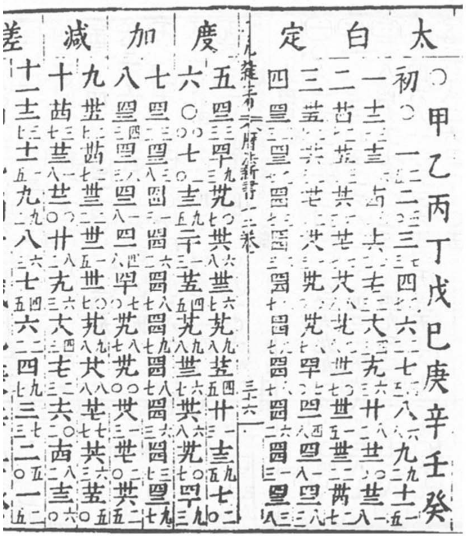
The *LFXS* features the most compact version of this table. Its title, 'Taibai dingdu jiajiancha' 太白定度加減差 (Correction for the fixed [true] degree of Venus), is placed above the table. The table is laid out in twelve columns and ten rows for a total of 120 cells. The twelve columns run right-to-left from the "beginning" 初 to "eleventh" 十一 signs (sign 0 to sign 11) into the zodiac, while the rows divide each sign into ten *xian* 限 'limits' enumerated by the ten heavenly stems (see fig. 12). Each sign of the zodiac is thus divided into ten three-degree segments. The table is provided with the following instructions:

> 求第二加減差
>
> 視其星自行定限立成下加減差，本行與後行相減，餘以乘限下小餘，得其分秒。視加減差少如後行者加之，多如後行者減之，即所求第二加減差也。
>
> Finding the second correction:
>
> Look at the planet's *zixing dingxian* (the argument are expressed with respect to *xian*) to find the *jiajiancha* from the table. Subtract the current line from the [*jiajiancha* of] the next line and multiply by the remainder under the *xian* to get its (the *jiajiancha*'s) minutes and seconds. If the *jiajiancha* is smaller than that of the next line, then add it; and if it is greater than the next line, then subtract it. The result is the second correction that you seek (*Lifa xinshu*, 2.13a).

Unlike the *BL-HHLF*, this table omits *jiajianfen*. Therefore, interpolation requires the user to find the difference between successive *jiajiancha* 'second corrections' himself. To use the table, one finds the *jiajiancha* from the sign and *xian* of the *zixing dingdu* argument, then arrives at the value of correction through interpolation.

In terms of number format, this table is quite unique. First, its values are base-100 (centesimal system), rather than base-60 (sexagesimal system). Furthermore, the integer number of degrees is written in large characters above small characters representing the fractional remainder, e.g. writing 一五二 for 1.25° (=1°15′).

Figure 12. *LFXS* second equation table for Venus ('Taibai dingdu jiajiancha' 太白定度加減差)



Title of the table												
Sign 11	Sign 10	Sign 9	Sign 8	Sign 7	Sign 6	Sign 5	Sign 4	Sign 3	Sign 2	Sign 1	Sign 0	○
12 73	24 73	35 72	43 34	42 23	0 00	42 33	43 34	35 72	24 73	12 73	0	甲
11 51	23 81	34 72	42 38	43 83	7 01	40 39	43 79	36 52	25 05	13 06	1 52	乙
9 29	22 00	32 22	42 81	44 31	13 59	39 70	44 73	37 02	26 36	14 28	2 05	丙
8 36	20 28	32 51	41 84	44 26	20 31	36 86	44 36	38 31	27 77	16 20	3 37	丁
7 54	19 36	31 70	40 07	44 78	25 54	33 76	44 78	39 00	28 88	17 32	4 79	戊
6 22	18 34	29 89	39 78	44 79	29 89	29 89	44 79	39 78	29 89	18 34	6 22	己
4 79	17 32	28 88	39 00	44 78	33 76	25 54	44 78	40 07	31 70	19 36	7 54	庚
3 37	16 20	27 77	38 31	44 36	36 86	20 31	44 26	41 84	32 51	20 28	8 86	辛
2 05	14 28	26 36	37 02	44 73	39 70	13 59	44 21	42 81	32 22	22 00	9 29	壬
1 52	12 06	25 05	36 52	43 79	40 39	7 02	43 83	42 38	34 72	23 81	11 51	癸

Because the *Mingshi*-series *Huihui lifa* are comparatively late, their tables bear unmistakable marks of European influence in terms of layout and formatting. For example, the title of the *MS-HHLF* table, 'Jinxing di'er jiajian yuanjin licheng' 金星第二加減遠近立成 (Second correction table for Venus in *jianjian* and *yuanjin*), is placed at the beginning of the table on its right, but the table itself adopts a rotational symmetry layout.

This 'rotational symmetry layout' divides the twelve zodiacal signs in two, with the first six running right-to-left across the top of the table, and the last six running left-to-right at its bottom. The argument is located on the left and right sides of the table. Above the right column is written the character *shun* 順 'forward' beneath *yinshu* 引數 'argument' (a Jesuit neologism), indicating that its values, which run from 0° to 30°, should be read top-to-bottom. Above the left column is written *ni* 逆 'reverse,' indicating that its values, also 0° to 30°, run bottom-to-top (see fig. 13). When using the table, one reads from the column appropriate to the half of the zodiac in which the argument falls, reading in the direction appropriate to that column. Because the values for the two halves of the zodiac are symmetrical in the *Huihui lifa* tables for the planetary equation of center—a result of having been calculated from trigonometric functions—the 'rotational symmetry' layout allows the size of the table to be reduced by half.

Figure 13. *MS-HHLF* second equation table for Venus ('Jinxing di'er jiajian yuanjin licheng ' 金星第二加減遠近立成)

Argument	Sign 2			Sign 1			Sign 0			Argument	Title of the table
	Yuan jin	*Jiajian cha*		*Yuan jin*	*Jiajian cha*		*Yuan jin*	*Jiajian cha*			
逆	Min.	Min.	Deg.	Min.	Min.	Deg.	Min.	Min.	Deg.	顺	
30	33	22	42	16	22	21	00	00	00	**0**	
29	43	54	42	61	74	21	1	62	1	**1**	
28	53	70	52	71	21	31	1	15	0	**2**	
27	53	03	52	81	63	31	2	51	1	**3**	
26	63	35	52	81	00	41	2	04	1	**4**	
25	73	51	62	91	52	41	3	50	2	**5**	
… …	… …	… …	… …	… …	… …	… …	… …	… …	… …	… …	
… …	… …	… …	… …	… …	… …	… …	… …	… …	… …	… …	
6	25	31	23	02	00	22	21	55	90	**24**	
5	35	43	33	13	42	22	21	02	01	**25**	
4	45	55	33	13	74	23	31	44	01	**26**	
3	55	61	43	23	11	23	41	90	11	**27**	
2	55	63	43	23	53	23	41	43	11	**28**	
1	65	65	43	33	85	23	41	85	11	**29**	
0	75	61	53	33	22	24	61	22	11	**30**	
	Sign 9			Sign 10			Sign 11				

The table's output includes both *jiajiancha* and *yuanjindu*, and the values of the former are divided into higher and lower unit parts. Unlike the *BL-HHLF*, this table omits the *jiajianfen* to save space. The key is similarly concise:

> 以其星自行定度入本星第二加減立成，内取其度分，用比例法加減之，同前。
>
> Find the degrees and minutes from the argument of the *zixing dingdu* in said planet's second correction table, then use the 'proportion method' to add or subtract it as above (*Mingshi*, 37.8b).

In other words, one is to use the 'proportion method' (*bilifa* 比例法) introduced here to perform interpolation—an operation similar to the linear interpolation of the *BL-HHLF*.[27]

In terms of number format, this table uses the abbreviated Chinese place value notation. Let us say, for example, that we need to find the correction for a *zixing dingdu* of 3°. First, we determine that 3° is located in the sign 0,

[27] The term *bilifa* 'proportion method' was coined by Jesuits translating works of European astronomy and mathematics into Chinese in the late Ming to refer to a method of performing linear interpolation through the use of proportional relationships. The *locus classicus* for this term is *Jihe yuanben* 幾何原本, the Chinese edition of Euclid's *Elements*.

and thus the first half of the zodiac. So, we read down the entries of sign 0, following *jiajiancha* column of the sign 0 to the third cell, reading the *yinshu* 'argument' from top-to-bottom, and pick up the respective degree ("1" 一) and minute ("15" 一五) values to arrive at 1°15′.

Variation and the Question of Transmission

The comparison reveals that the difference between our four versions of second equation tables for Venus comes down to layout rather than content. These changes, I argue, are actually related to the nature and intended audience of each work. For the sake of discussion, I have distilled the characteristics of the four tables examined above into Table 2.

Table 2. Comparison of second equation tables for Venus[28]

Source	Vols.	Entries	Operation	Accuracy	Intrpltn.	Characteristics
BL-HHLF	5	1080	Complex	Very Good	need	For official use at the Astronomical Bureau
XYLFTJ	24	2640	Simple	Good enough	no need	Expanded edition; sufficient for calculating astrological 'encroachments', etc.
LFXS	5	120	Medium	Not Good enough	need	Recompiled based on traditional Chinese methods
MS-HHLF	3	558	Complex	Very Good	need	Tables simplified and compressed in European style for inclusion in state history project

First, Bei Lin began to compile a new edition of this text in 1470, which the *BL-HHLF* colophon tells us that he completed in the autumn of 1477. There, Bei Lin states that his reason for revising this book is that, during his time as assistant director of the Astronomical Bureau, he was worried that the *Huihui lifa* compiled by Yuan Tong, et al. during the Hongwu reign-period "had disappeared over the years" 歲久湮沒 to the point that it "might be abandoned and cease authentic transmission" 廢弛而失真傳, and so he wanted to "circulate it at the Bureau… so as to aid later learners with its astronomical calculations" 傳之監台…以益後學推曆 (*BL-HHLF*, 1.32).

[28] The "Vols." indicates the volumes of each works and the number of "Entries" shows the capacity of the second equation tables for Venus in each works.

Clearly, the complexity and precision of this edition's interpolation procedures was intended for the educational and practical needs of the Bureau's Islamic astronomy experts. Bei Lin came from a military family and took up the study of astronomy as a pathway away from military life. Upon the completion of his studies, he served the military in an astrological function, and then returned to the Astronomical Bureau, where he worked his way up to assistant director.[29] Bei Lin's early work is primarily focused on astrology, and his work on Islamic astronomy was probably limited to his revision of the earlier *HW-HHLF*. His background would suggest that tables in his *BL-HHLF* are probably simple revisions of the *HW-HHLF* ones.

Liu Xin's *XYLFTJ*, on the other hand, completely recalculated and reorganized these tables. Families of Near Eastern astronomers monopolized the operation of Islamic astronomy in the early-Ming Astronomical Bureau. Furthermore, due to its incongruity with the Chinese tradition, the number of Chinese with a complete grasp of Islamic astronomy was extremely limited. As such, the fact that Liu Xin was able to recalculate these tables goes to show that he possessed an uncommon understanding of the subject. This, it seems, was due to a family background in the field. His grandfather, Liu Bowan 劉伯完 (fl. 1403) had once "served concurrently as assistant director of the Astronomical Bureau and the Huihui Astronomical Bureau" 曆欽天監兼回回監副,[30] and was reported to be "proficient with prognostication and familiar with Huihui astronomy" 精於占候,又諳回回曆法.[31] What also makes these tables unique is that they are enormous (more than twenty-four volumes), precise, and easy to use, which shows that he must have spent a lot of time and hard work on their production. Xu Youzhen 徐有貞 (1407-1472) offers the following characterization of him in his preface:

> 予友劉中孚，知星曆，博極群術，而旁通西域之學。嘗以其曆法舛互，無一定之制，歲久寖難推步。為之譯定其文，著凡例、立成數以起算。約而精，簡而盡，易見而可恒用，秩然成一家。書將以傳之，為其學者，其用心亦勤矣。
>
> My friend (Liu Xin) understands astrology, has a broad understanding of its multifarious techniques, and has mastered the knowledge of the Western Regions. He was concerned that astronomy had become confused, and that, without a single standard, later ages would find it increasingly difficult to operate. To this end, he translated and fixed its language and composed examples and tables to pick up and calculate. His numbers were simple but accurate, concise but complete, easy to see but for perpetual use, and so orderly as to be a work unique unto itself. I

[29] Chen Jiujin (1996), p. 52.

[30] *Jiangxi tongzhi* 江西通志, 77.24b; cf. Chen Zhanshan 陳占山 (2009), p. 208.

[31] *Xichao mingchen shilu* 熙朝名臣實錄, 6.14b.

> have written this [preface] to make it known all the hard work that he has put into his studies.[32]

In addition to addressing Liu Xin's proficiency with Islamic knowledge and editorial intent, the fact that the preface describes the tables as "simple but accurate, concise but complete, easy to see but for perpetual use" confirms that accuracy of calculation and ease of use were indeed their hallmarks.

In another preface, Xu Youzhen also tells us that Liu Xin "composed an 'Essentials for the Quick Calculation of Encroachments' to redress the insufficiencies of its predecessors" 嘗著《淩犯曆捷要》補前人之未備, seemingly referring to the *XYLFTJ* 'Lingfan shike licheng' 淩犯時刻立成(Tables for the instant of encroachment).[33] Such tables, which are extremely rare in works of Islamic astronomy, occupy three volumes (vols. 21-23) of the *XYLFTJ*, suggesting that its main purpose was indeed the calculation of encroachments.

Every year the Ming Astronomical Bureau needed to compile a report of lunar and planetary encroachments for that year to meet the court's astrological needs. For example, the 'Xuande shinian yue wuxing lingfan' 宣德十年月五星淩犯 (The lunar and planetary encroachments for the 10th year of the Xuande reign-period; hereafter *XSYWLF*) forecasts more than 325 instances of encroachment over the course of the year 1435. If one wanted to calculate these encroachments, one would have to compare calculations of daily lunar and planetary positions with the positions of the fixed stars in the *Huihui lifa* catalog. There is no doubt that the accuracy and ease of Liu Xin's tables would have greatly simplified such a task, especially because the tables are large and do not require interpolation. It is for this reason that we may surmise that the effort that he spent recompiling said tables was for the sake of calculating encroachments.

The contents of Yuan Huang's 袁黄 (courtesy name Liaofan 了凡; 1533-1606) *LFXS* are derived from the oral instruction of his teacher, Chen Rang 陳壤. According to the *Chouren zhuan* 疇人傳:

> 陳壤字星川，吳郡人也，以太一、天、地、人三元附合回回術法，嘉靖間曾上疏改曆，格而未行。
>
> Chen Rang, whose courtesy name was Xinchuan, was a man of Wu Commandery. He synthesized the epoch Taiyi and the three eras (Heaven, Earth, and Man) with Islamic [techniques and models]. In the Jiajing reign-period (1522-1566) he petitioned to implement astronomical reform without success (*Chouren zhuan*, p. 332).

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32 "Xiyu lifa shu xu" 西域曆法書序, in *Wugong ji* 武功集, 2.21a.

33 "Zeng Qintianjian zhubu Liu Zhongfu xu" 贈欽天監主簿劉中孚序, in *Wugong ji*, 3.6a.

Chen Rang was dissatisfied with the fact that the late-Ming Astronomical Bureau was "falsifying their numbers each time they calculated an eclipse to hide their mistakes" (每推步日月交食，辄虚加其数，以掩其失) (*LFXS*, 5.51). He therefore decided to pursue astronomical reform on the basis of the *Datong li* and *Huihui lifa*, which is why the *LFXS* abandoned 96-*ke* 刻 day and sexagesimal minutes and seconds in favor of the *Datong li*'s traditional decimal time scheme. Furthermore, in making the dimensions of his book's tables extremely small, he was continuing on the vein of the economy of traditional Chinese tables. Yuan Huang's *LFXS* took Islamic astronomical knowledge restricted to internal use within the Astronomical Bureau and revised and introduced it to the public sphere by synthesizing it with familiar traditional forms of Chinese astronomy. Prior to the compilation of the *Mingshi gao* and *Mingshi* astronomical treatises, the *LFXS* was one of the only points of access to Islamic astronomy and was an important catalyst in expanding public interest and knowledge of the subject beyond the confines of state service. Indeed, the public was so ignorant of Islamic astronomy that scholars of the time mistook Yuan Huang's *LFXS* as the *Huihui lifa*. According to Mei Wending 梅文鼎 (1633-1721), for example, "when people see that Liaofan's book uses a lot of Huihui methods they then mistake it to be the Western-Region Tupan method" 人惟見了凡之書多用回回法，遂誤以為西域土盤法耳 (*Lixue yiwen* 曆學疑問, 1.13b).

One characteristic of the *Mingshi*-series *Huihui lifa* is that they omit tables related to mean motion (the first ten tables of the *BL-HHLF*). Instead, the *MS-HHLF* reads:

> 原本總年、零年、月分、日期及十二宮初日凡五立成，每立成內首列本立成年、月、日宮各紀數，次列七曜、次列日中心行度，及土、木、火、金、水各自行度，日、五星最高行度。文多不錄，錄其造立成法於左。
>
> The original includes a total of five tables: average year, individual year, month, day, and the first day of each sign. At the head of each table is listed the identifying numbers of the year, month, day, and sign, following which is listed the Seven Luminaries (week days), following which is listed the position of the mean sun, Saturn, Jupiter, Mars, Venus, and Mercury and apogee of their epicycle. Rather than recording that text in all its length, we offer the following instructions for constructing these tables (*Mingshi*, 38.1a).

The *MS-HHLF* does this for two reasons. First, the theory behind the mean motion tables is comparatively simple, necessitating only the addition and multiplication of astronomical parameters. Second, the *MS-HHLF* was compiled for the sake of historical interest rather than use, and the omission of these tables saves it a considerable amount of space. The idea was Huang Zongxi's 黃宗羲 (1610-1695), who writes:

> 關係一代之製作，不得以繁冗而避之也。以此方之前代可以無愧，然前代顧亦有未盡善者，前代曆志雖有推法，而立成不能盡載。…蓋作者之精神盡在於表，使推者易於為力，今既不可盡載，而徒列推法，是則終於牆面而已，某意欲將作表之法載於志中，使推者不必見表而自能成表，則尤為盡善也。
>
> The compilation of [an 'Astronomy Treatise'] is a production of a generation. We could not eschew it simply because of the complexity and enormity of the task; it is only by taking it up that we would not feel ashamed before earlier generations [of compilers]. And yet, the work of previous generations had not been perfect either: though their 'Astronomy Treatises' had calculations, they could not include all of the related tables. … The spirit of the author is complete in his tables, which save [the reader] the effort of calculation. Now, we cannot include all the tables here, and we would run up against a wall if we were to provide only formulae instead. My suggestion is that we record the methods of producing the table in the treatise so that the calculator (reader) may make do without the tables as he would be able to make them himself—this would be perfect.[34]

Faced with the dilemma that "the spirit of the author is in his tables" and that they "could not include all of the tables," the provision of do-it-yourself instructions allows the *MS-HHLF* to preserve the information of the tables at considerable savings in space.

The most conspicuous characteristic of the *Mingshi*-series is the European influence evident in its tables, especially the use of rotational symmetry. Again, this is quite distinct from traditional tabular layouts in terms of directionality and formatting. The *NJ-HHLF* attaches the following small-character explanation to its first table:

> 原本各項宮度分秒本行直書，今依西洋表法，另列於直次行，橫查之。每格分兩位，右為十，左為單，約法也，餘仿此。
>
> The original edition presented each item—sign, degree, minute, and second—in vertical writing. Here we follow the Western Ocean (European) method, separating them

[34] 'Huang Lizhou da Wanzhenyi lun *Mingshi* Li zhi shu' 黃梨洲答萬貞一論明史曆志書 (Huang Lizhou's [Xizong] letter in response to Wan Zhenyi's discussion of the *Mingshi* Astronomical Treatise), in *Mingshi li'an* 明史例案, 8.6a.

> into different lines that are to be read horizontally. Each cell is divided into two places, with the tens on the right and the units on the left—this is the abbreviated method, and similarly elsewhere.[35]

At the same time that the reading-direction is changed from vertical to horizontal, the entries of the original book—written out in the form "sign A, degree B, minute C, second D" 某宮某度某分某秒—are changed to numbers representing higher and lower units and placed in different cells.

In the key to its solar equation table, the *MS-HHLF* mentions that the reason for switching to the 'rotational symmetry' layout was that:

> 自行宮度為引數，原本宮縱列首行，度横列上行，每三宮順布三十度，内列加減差，又列加減分。其加減分乃本度加減差與次度加減差之校也，今去之，止列加減差數。將引數宮列上横行，度列首直行，用順逆查之，得數無異，而簡潔過之，月、五星加減立成準此。

> The epicyclic mean anomaly (*zixing gongdu* 自行宮度) is the argument (*yinshu*). In the original edition, the signs are placed vertically in the head column and the degrees were listed in the top row, laying out thirty degrees for each sign, within each of which were listed *jiajiancha* and *jiajianfen*. The *jiajianfen* is the difference between the *jiajiancha* of that and the next degree. We omit this here, listing only the *jiajiancha* numbers. Listing the sign-argument in the top row and the degrees are listed in the head of vertical column allows the table to be read forwards and backwards, such that it is succinct to look through and one always finds the right number. The lunar and planetary correction tables have [also] been organized according to this principle (*Mingshi*, 38.8b).

From this description, we can ascertain that the layout of the tables in the "original" was identical to the *BL-HHLF*, the reason for reproducing them in the rotational symmetry layout being that "it is succinct to look through and one always finds the right number." The reasoning here is essentially the same as that guiding the decision to replace the mean motion tables with do-it-yourself instructions: the preservation of the most amount of information in the least amount of space. As the *Huihui lifa* had already been retired by the time of compilation, the aim of this recension was to produce a concise record for inclusion in a history—an aim diametrically opposite that of, for example, Liu Xin's *XYLFTJ*.

The rotational symmetry layout was common in Arabic astronomical tables, especially those for the equation of center. It is possible that this

[35] Cf. Tao Peipei 陶培培 (2003), p. 119.

gradually went on to influence the European tradition, where it became a common organizing principle for astronomical tables.[36] It is clear, however, that rotational symmetry was, with the sole exception of the aforementioned parallax correction tables, not a feature common to Ming-era *Huihui lifa* works but a product of later Jesuit influence.

In 1629, Xu Guangqi 徐光啟 (1562-1633) organized a project to compile the *Chongzhen lishu* 崇禎曆書 (Treatises on the Astronomy of the Chongzhen Reign-period [1628-1644]; hereafter *CZLS*) through the combined efforts of Chinese scholars Li Zhizao 李之藻 (1565-1630) and Li Tianjing 李天經 (1579-1659) and members of the Jesuit mission to China, Nicholas Longobardi (1559-1654), Giacomo Rho (1593-1638), Johann Schreck (1576-1630), Johann Adam Schall von Bell (1591-1666). Finished in 1634, the *Chongzhen lishu* would become one of the age's most important introductions to European astronomy. Unfortunately, conservative pressure at court kept the Ming government from enacting astronomical reform until 1643, at the very brink of its oblivion. In order to maintain the Jesuit mission's place at in the Chinese Astronomical Bureau, Schall von Bell subsequently renamed the work *Xiyang xinfa lishu* and presented it to the newly established Qing court. Later, in 1713 and 1738, Jesuit astronomers compiled the *Lixiang kaocheng* 曆象考成 (Thorough Investigation of Calendrical Astronomy; hereafter *LXKC*) and *Lixiang kaocheng houbian* 曆象考成後編 (Later Compilation of the Thorough Investigation of Calendrical Astronomy; hereafter *LXKCHB*) on the basis of this work.

The *CZLS*, *XYXFLS*, *LXKC* and *LXKCHB* tables widely adopt the principle of rotational symmetry. The rotational symmetry of the *LXKC* and *LXKCHB* tables is almost identical to the *Mingshi*-series ones, for example, with the exception that the position of higher and lower units have been reversed such that the 'degree' is written to the left of the 'minute' (see fig. 14). The earlier *CZLS* and *XYXFLS* tables also differ slightly from the *Mingshi*-series in two regards. First, they have in effect been rotated 90°, such that the zodiacal signs run down the right edge of the table, and the arguments across the top and bottom. Second, the data are abbreviated to the place-value, rather than written out, but are written vertically as per tradition (see fig. 15). In sum, early attempts at reproducing the 'rotational symmetry' of European astronomical tables abided by a number of more traditional characteristics of Chinese tables, while later attempts were more perfect and standardized, tending more towards the European style.

[36] Husson (2014).

**Figure 14. *LXKC* and *LXKCHB* solar equation table
('Taiyang junshu biao' 太阳均数表)**

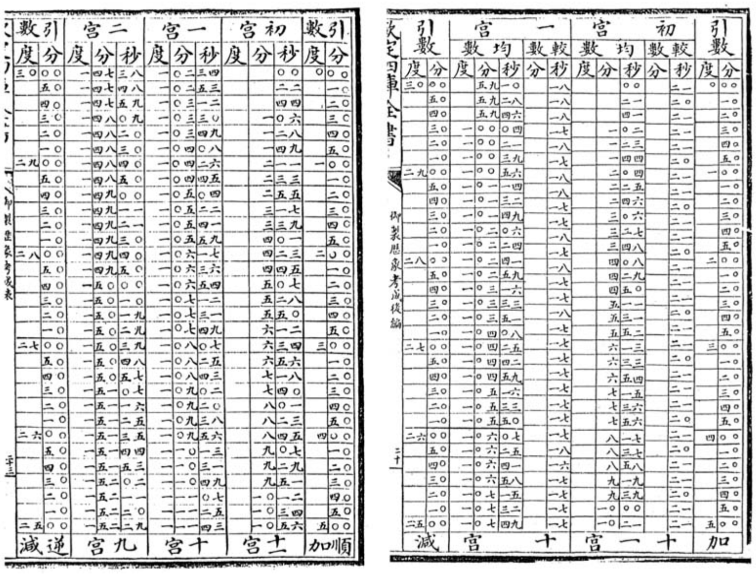
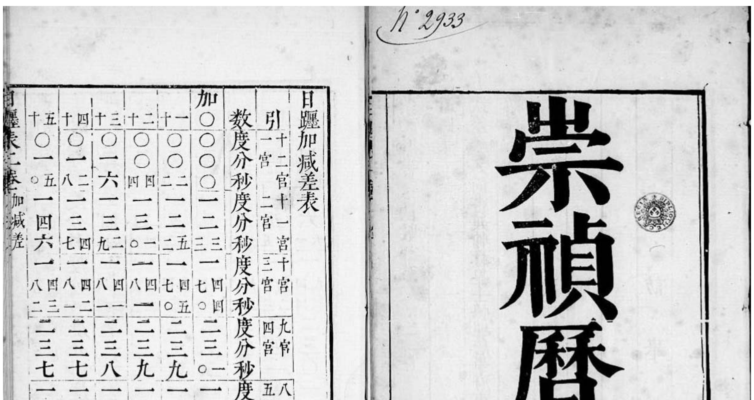


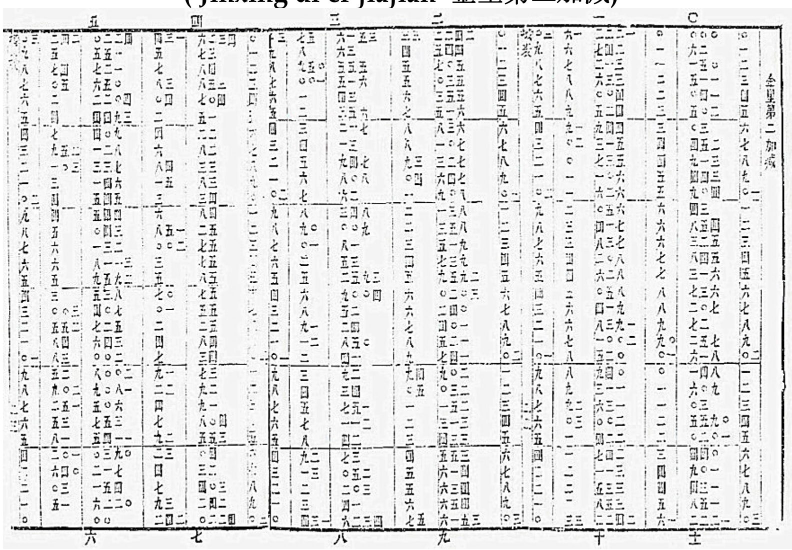
**Figure 15. *CZLS* solar equation table
('Richan jiajian biao' 日躔加减表)**



SOURCE: Bibliothèque Nationale de France copy.

In actuality, the first *Huihui lifa* work to switch to the principle of rotational symmetry in its tables was Xue Fengzuo's, which has been collected in his *Lixue huitong* 曆學會通 (Compendium of Mathematical Astronomy). Originally titled *Tianbu zhenyuan* 天步眞原 (True Principles for the Pacing of Heaven), the *Lixue huitong* was joint translation by Xue and his teacher, the Polish Jesuit Nikolaus Smogulecki (1611–1656), finished in 1664. Shi Yunli (2000) has identified this as a translation of the Belgian astronomer Philip von Lansberge's (1561-1632) *Tabulae motuum coelestium perpetuae* of 1632, making this the earliest introduction of Copernican tables to China. In addition to introducing the state of the field in Europe, the *Lixue huitong* collects the Ming *Datong li* and *Huihui lifa*, the latter of which Xue reorganizes according to European layouts. "Western-Region (Islamic) astronomy came before the Western-Ocean (European), just like the *Shoushi li* (1281) had the *Jiyuan li* (1106) and *Kaixi li* (1207) [before it]" 西域曆在西洋之前，亦猶授時之有紀元、開禧等曆也, and so Xue Fengzuo argued to include it in his collection because "while the reform and promulgation of the new methods might seem to obviate this, there is a lack of textual evidence about the origin and development of these theories sufficient to cast doubt upon many of its points" 新法改政頒佈，當不需此，然諸說之所由來與沿革之所自起，文獻無征，足見疑端 (*XFZ-HHLF,* 1.1a). While the *XFZ-HHLF* tables for the equation of center do feature rotational symmetry (see fig. 16), it is of a comparatively simple fashion somewhere between the *CZLS/XYXFLS* and the *LXKC/LXKCHB* in terms of style.

Figure 16. XFZ-HHLF second equation table of Venus ('Jinxing di'er jiajian' 金星第二加減)



SOURCE: Kangxi (1661-1722) edition from the Peking University Library.

In terms of date, the *MSG-HHLF* and *MS-HHLF* were published in 1723 and 1739, respectively, the *NJ-HHLF* was produced around the beginning of the eighteenth century, and the earliest *Huihui lifa* to utilize rotational symmetry was the *XFZ-HHLF* of 1664. All of these postdate the aforementioned works on European astronomy, and the *NJ-HHLF* frequently introduces such tables with “here we use the Western Ocean style of tables” 今依西洋表法. Therefore, we may conclude that the rotational symmetry of the *Mingshi*-series *Huihui lifa* was inspired by European works and Xue Fengzuo’s approach to tabular layout.

Here, the reason for this layout was not simply spatial economy. For many early-Qing scholars, the distinction between the ‘Western Regions’ (*Xiyu* 西域; i.e. Islam) and the ‘Extreme West’ (*Jixi* 极西), ’Far West’ (*Yuanxi* 遠西), and ‘Great West’ (*Taixi* 泰西) that came later was somewhat nebulous. Furthermore, many believed that European and Islamic astronomy shared a common origin and were substantially the same. For example, in ‘Lun Huihui li yu Xiyang li tongyi’ 論回回曆與西洋同異 (On the Differences between Huihui and Western Ocean Astronomy), Mei Wending states that “Huihui and European—that is, Western Ocean—astronomy share a common origin; Huihui astronomy is simply the predecessor of Western Ocean astronomy” 回回與歐羅巴即西洋曆同源，回回曆即西洋舊法耳 (*Lixue yiwen*, 1.11). Huang Zongxi suspected that “*Chongzhen lishu* was largely rooted in the Huihui” 《崇禎曆書》大概本之回回,[37] as too did Xue Fengzuo (above). While the Chinese may have been unclear about the differences of Arabic and European astronomy, they did have a correct understanding of the common origin of these traditions of astronomy. This also makes sense that they would combine the two.

Though they were born into different times and different circumstances, Xue Fengzuo, Huang Zongxi, and Mei Wending all had broad contact with missionaries, backgrounds in Western astronomy, and favorable opinions of its merits. Add to this that rotational symmetry offered space-saving advantages and the genetic relationship between Islamic and European traditions of astronomy, and it is easy to understand why the compilers of the *MS-HHLF* adopted this European convention to Islamic tables.

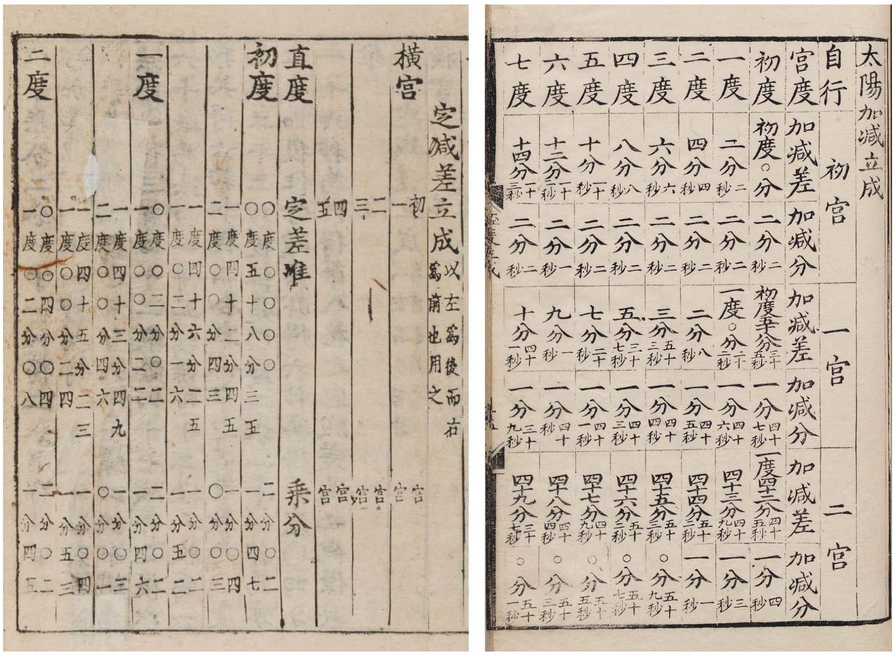
[37] ‘Huang Lizhou da Wanzhenyi lun *Mingshi* Li zhi shu’ 黃梨洲答萬貞一論明史曆志書 (Huang Lizhou’s [Xizong] letter in response to Wan Zhenyi’s discussion of the *Mingshi* Astronomical Treatise), in *Mingshi li’an* 明史例案, 8.6a.

Tables for Solar Equation of Center

In the previous section, we used the example of the *Huihui lifa* 'Second equation table for Venus' to illustrate variations in tabular layout and number formatting and the reasons behind them. In this section, we turn to the 'Taiyang jiajiancha licheng' 太陽加減差立成 (Table for solar equation) as another example of how Arabic astronomical tables were influenced by Chinese, Islamic, and European styles over the course of their use in China. Namely, these tables transitioned from one- to two-dimensional arrays before ultimately adopting rotational symmetry, reflecting a move in tabular layout from Chinese to Western traditions.

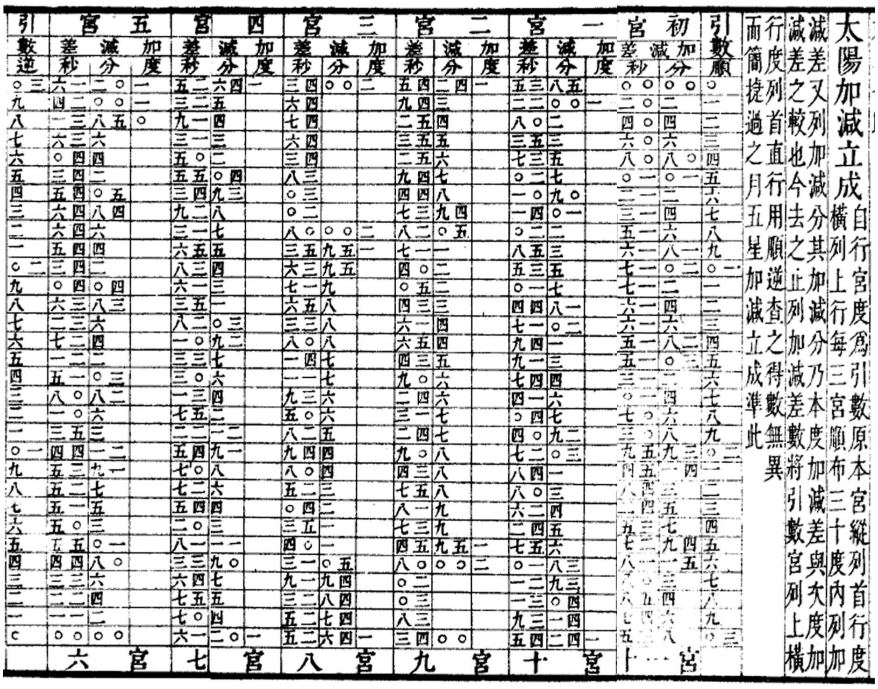
While the *HW-HHLF* is no longer extant, we can still get a glimpse of the earliest processes of translation through the 1396 *Weidu taiyang tongjing*, which Yuan Tong, et al. compiled on the basis of the *HW-HHLF*. The *Weidu taiyang tongjing* is, for all intents and purposes, an adequate representative of the early state of Islamic astronomical tables in China. Therein we find a 'Taiyang dingjiancha licheng' 太陽定減差立成 (Table for fixed solar correction) that is completely identical with other *Huihui lifa* works except for its layout. The commentary to the table instructs the user "take the left as the end, the right as the beginning, and use it" 以左為後，而右為前也，用之 (*Weidu taiyang tongjing,* 1.24) in accordance with the Chinese practice of reading right-to-left, and at the beginning of the table is written "rows = signs" (*henggong* 横宮) and "columns = degrees" (*zhidu* 直度). The table's *dingchazhun* 定差准 (fixed correction standard) and *chengfen* 乘分 (the interval between corrections) are identical to the *jiajiancha* and *jiajianfen* values of the corresponding table in the *BL-HHLF*, respectively, and are thus alternative names for the same concepts. The layout of the *BL-HHLF* table is identical to that of its 'Table for the second correction for Venus' (above) in that it features a two-dimensional array, which is to say that it juxtaposes outputs for each sign at arguments of 0° to 30°, enumerating the *jiajiancha* value for each sign in separate cells. In the one-dimensional array of the *Weidu taiyang tongjing* table, on the other hand, each cell includes an array of six values that correspond, in order, with the six zodiacal signs treated in the table (see fig. 17).

Figure 17. *WDTYTJ* (left) and *BL-HHLF* (right) tables of solar equation of center



The 'one-dimensional array' is a common feature of traditional Chinese astronomical tables, and its presence in the earliest translation of the *Huihui lifa* very clearly harkens back to that tradition. The 'two-dimensional array,' on the other hand, is typical of Arabic tables, and thus we may surmise that its presence in the *BL-HHLF* reflects an influence wrought of the continual use and absorption of Islamic tables. Finally, 'rotational symmetry' is a hallmark of European tables, and the fact that it appears in the *MS-HHLF* tables (see fig. 18) reflects the creative readaptation of Arabic tables in the image of those transmitted to China by the Jesuit mission. In the end, this evolution highlights the adaptive, synthetic attitude that Chinese astronomers took towards the mathematical tables of foreign civilizations.

Figure 18. *MS-HHLF* table for solar equation ('Taiyang jiajian licheng' 太阳加减立成)



Concluding Remarks

First, clues about the use of Arabic parallax correction tables in China have allowed us to determine that the Yuan Imperial Secretariat held a large number of Arabic astronomical tables that were, to some extent, those adopted by the Huihui Astronomical Bureau. These were then translated into Chinese by a number of Muslim and Chinese astronomers at the order of Ming Taizu, Zhu Yuanzhang. These tables—whose contents and layout had undergone adjustment in the process—formed the earliest *Huihui lifa*, which saw prolonged use over the course of the Ming dynasty for the sake of predicting encroachments and eclipses.

Second, in the centuries following its translation, a large number of related works sprung out of the original *HW-HHLF*. During this process, the contents of the *Huihui lifa* tables remained basically unchanged, but a diversity of tabular layouts gradually emerged. Examination of each work's nature and characteristics reveals that their reorganization was done with specific readerships and usages in mind.

The existence of Arabic-language manuscripts from the Yuan and early-Ming intimates that the use of such tables was restricted to the families of Near Eastern astronomers who served the court. Once the *Huihui lifa* had been translated into Chinese in the early-Ming, it began to meet the educational and computational needs of the Chinese members of the Astronomical Bureau. However, the substantial discrepancy between traditions ensured that it was only ever mastered by a very limited number of Chinese astronomers. According to Mei Wending, for example, "In the contexts of Huihui astronomy tables are compiled by the lunar year, but use solar years to count from epoch, thus ingeniously hiding its roots" 回回曆以太陰年列立成，而又以太陽年查距算，巧藏其根 (*Lixue yiwen*, 1.14), which is to say that Islamic astronomers intentionally obfuscated the methods of the *Huihui lifa* to ensure their monopoly on the offices of the Astronomical Bureau.

However, there were still a handful of Chinese astronomers like Liu Xin in the early-Ming who were able to take advantage of good relations with Islamic lineages to learn their methods. Liu's recalculation and reproduction of Arabic astronomical tables obviated the task of interpolation in his *XYLFTJ*, greatly improving the efficiency with which one could use such tables.

As the need for astronomical reform became apparent in the late Ming, Bureau outsiders like Chen Rang participated in policy reform efforts, which afforded them access to formerly restrict state knowledge of Islamic astronomy. Chen Rang revised and synthesized the *Huihui lifa* with traditional Chinese methods of astronomy, converting the sexagesimal notation of the tables to centesimal, and transmitting them to his own disciples. His student Yuan Huang finally compiled from this the *LFXS*, which one could say first brought Islamic calendrics from the official to the public sphere, affording even more scholars access to this knowledge.

While the Qing abandoned Islamic astronomy, people like Xue Fengzuo recorded the *Huihui lifa* in books for the sake of preservation. He once a student of European astronomy under the Polish Jesuit missionary Nikolaus Smogulecki, Xue Fengzuo was the first to recompile the *Huihui lifa* tables in the European 'rotational symmetry' layout. Then, when the Qing government set about compiling the *Mingshi*, Huang Zongxi built upon Xue's work due both to length requirements and his commitment to preserve as much of the tables as space allowed. Ultimately, this flexibility ensured that the *Mingshi* 'Astronomy Treatise' was able to preserve the *Huihui lifa* in its entirety.

Third, the transition from one- to two-dimensional arrays and the adoption of rotational symmetry reflects how Chinese astronomical tables continued to absorb the traditional strengths of Arab and European tables while at the same time flexibly adapting them to their own purposes on the basis of Chinese traditions and usages.

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